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Cover Kodak's Kodavision 8-mm camcorder for home use; photograph by Mike Malyszko
Inset: NBC's Chet Huntley using early-1960s camera/transmitter; source: Bettmann Archive

OPINION

How to meet the foreign challenge: put customers first

Industry after industry in the United States faces intense competition from overseas. To meet it, American corporations are automating factories, using R&D to improve product designs, and working to improve product quality. These are all worthy efforts. But foreign contenders can make similar moves. A Korean, Malaysian, or Japanese producer with automated factories, well-designed products, and good quality-control programs will continue to have the extra edge of low-cost labor.

Although the U.S. remains an innovative nation, trends relative to the rest of the world are not encouraging. Last year nearly 42% of U.S. patents went to foreign residents. Emerging nations have been increasing their percentage of technology graduates while the U.S. percentage has declined; a third of U.S. technology graduate students now come from overseas. And other nations orchestrate national R&D programs aimed at speeding up the advance of technology for critical industries.

So where can U.S. manufacturing industries hope to gain an edge? In fact, a domestic manufacturer has a tremendous potential strength relative to offshore competitors simply by being closer to the market. Amazingly, few American firms make much use of this obvious advantage. Truly caring about customers, finding out what they really want, and better meeting their needs are not fundamental to management thinking in many American companies. The focus is more on productivity, efficient distribution, cost cutting, and quick profits than on providing better service. Advanced technology is streamlining internal operations, but rarely is it used to expand communication with customers, offer them wider options, and improve services.

On the contrary, marketing in many industries is largely geared to manipulating customers into buying what the manufacturer wants to make. Strong competition from overseas is frequently the result of foreign manufacturers paying attention to customers rather than of government subsidies or low wages; many imports are actually more expensive than U.S. goods. American steel vendors wouldn't sell buyers the specials they needed, so European steelmakers supplied them and won new customers. Japanese automakers learned that car buyers were sick of arguing with the "service" departments of domestic car dealers, so they offered cars that needed fewer repairs.

Technology exists that could enable American vendors to easily meet such needs. Yet flexible manufacturing systems that could efficiently produce a wider assortment of products are not in great demand in most U.S. industries. How many U.S. manufacturers take the trouble to get real feedback from customers, or from potential buyers who did *not* make purchases? How many executives or designers ever get out into the marketplace to talk to their customers in person?

America's manufacturers, whether they make cars, steel, clothes, computers, machine tools, or thousands of other products for consumers or industry have a simple way to strengthen their positions: Do a better job of satisfying customers.

Robert Haavind

Robert Haavind

PAUL MOCK

high Technology

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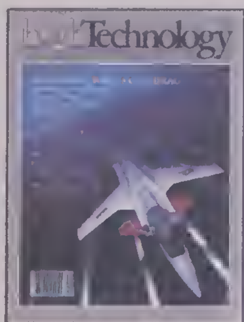

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LETTERS

Will the U.S. be second to one?

My compliments on your July Opinion regarding the American slide into second-rate economic status. While the U.S. is consumed by the alleged threat of the USSR, Japan pursues a policy that will put it into economic first place by 1990. Ironically, we are heading toward a Sovietized economy in the sense of producing first-rate military equipment but second- and even third-rate consumer items.

Robert Epstein
Oakland, Cal.

Your July Opinion succinctly and accurately describes a major problem in the U.S. caused by misuse of venture capital. If only American management and investors would heed your advice to put money into domestic technologies!

In a guest column in the same issue, John Young, CEO of Hewlett-Packard, calls on U.S. industry to take corrective action ("Meeting global competition" p. 12). However, Young's own company is as guilty of technological myopia as other industrial giants. We applied to many companies, including HP, for venture capital funds to start a digital laser disc manufacturing company and were rejected by all of them. They would rather let the Japanese increase their balance-of-trade advantage over the U.S. than invest in a company that could prevent further loss in the areas of compact disc and CD-ROM production.

Richard M. Block, President
Edgewood Industries
Scarsdale, N.Y.

Your July Opinion concerning the flood of high technology imports signals a danger that has not yet been perceived by most others in the general press. For years, decisionmakers in Washington have blithely watched imports take over one mass market after another, perhaps assuming that our lead in high technology would ultimately save the day. But the day has arrived, and we are seeing our high technology markets succumbing to targeted onslaughts from Japan, much the same way that consumer markets did earlier.

Why is it, then, that the media view any attempt on our part to balance trade as "protectionism" while Japan's efforts to maximize unbalanced trade advantages is termed "free trade"?

A. Daniel Eliason
Santa Barbara, Cal.

Shaping up the factory

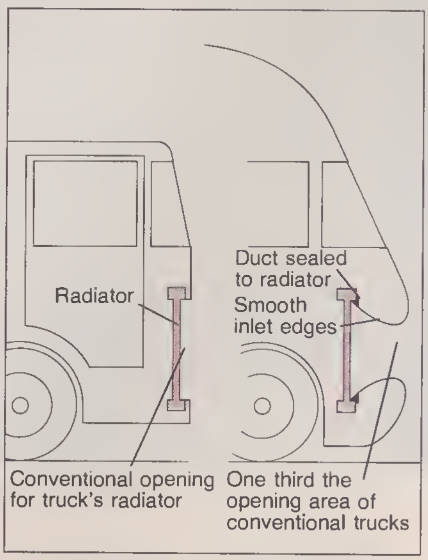
"Renaissance on the factory floor" (May, p. 25) leads readers to believe that a large investment in automation is required in order to realize the benefits of "just-in-time" (JIT) techniques.

I have seen several companies plan, design, and implement JIT programs and have found that the most cost-effective approach to these programs follows a three-step process of simplification, automation, and integration.

The objectives of simplification are to reduce long setup times, eliminate excessive work-in-process inventory buffers, and reorganize material flow into more of a repetitive process. The beneficial results can then be used, if desired, to selectively automate the now streamlined process. Integration is a longer-term program to provide the company with improved communications and responsiveness to the market.

Other approaches tend to computerize the existing inefficiencies on the shop floor, allowing mistakes to be made at the speed of light.

Scott A. Smith, Manager
Manufacturing Group
Arthur Andersen & Co.
New York, N.Y.



A conventional truck (left) is designed with a flat front to accommodate the radiator. Streamlining the radiator opening (right) would reduce drag on the truck without affecting the cooling system, according to Lambie.

Streamlining trucks

I'd like to add some thoughts to your interesting story "The truck of the future" (June, p. 28). I was chief consultant on a project headed by aeronautical engineer Paul MacCready that allowed me the freedom to try various ideas to reduce truck drag. One thing I found, contrary to points in your article, is that there is simply no need for a large, flat front on a truck to accommodate the radiator. The entry hole need be only about a third the size of the radiator cooling area. Naturally, a sealed duct from the hole to the radiator must be used.

I drove the test truck, which we called "The Drag Queen," fully loaded and up steep desert grades in over 100° weather with no overheating.

I am always amazed at the lack of crossover between aircraft and vehicle aerodynamics. What has been common practice for 60 years in getting sufficient air to liquid-cooled engines in aircraft has often had to be reinvented in land vehicles.

Jack Lambie, Consultant
Aerodyne
Tustin, Cal.

Flying safe, flying smart

In "Preventing midair collisions" (July, p. 48), the reader is led to the mistaken impression that under rules and procedures now in effect the 1978 midair collision over San Diego could not have occurred.

In the aftermath of the San Diego disaster, the Federal Aviation Administration imposed on San Diego a "terminal control area" (TCA) status, which designates that sections of airspace surrounding busy hub airports be closed to all aircraft not receiving permission to enter. The designation also allows for irregularly shaped airspace and imposes additional restrictions on aircraft flying into the area.

While many people saw the TCA as a solution, it did not change the conditions under which the San Diego disaster occurred; in fact, it created what some pilots see as an increased hazard in the area. The San Diego TCA has the effect of routing transient aircraft flying by visual flight rules—as opposed to instrument rules—either low over rugged terrain or through a narrow, winding corridor directly over the city. And the Byzantine design of this airspace can keep a pilot puzzling over his charts at the time when he should be rubbernecking for other traffic.

The TCA in San Diego would have made no difference to the pilots involved in the accident; both were flying by instrument rules under supervision of air traffic controllers. While airborne collision avoidance systems might certainly improve aviation safety, it appears no device will really work unless the brain is first engaged.

E. B. Everett, Jr.
Certified Flight Instructor
Los Angeles, Cal.

Correction: In "Managing the Industrial Miracle" (Aug.), the designer shown on p. 27 should have been identified as Masatoshi Shima of Intel. The photo was taken at the firm's Design Center in Tsukuba, Japan.

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

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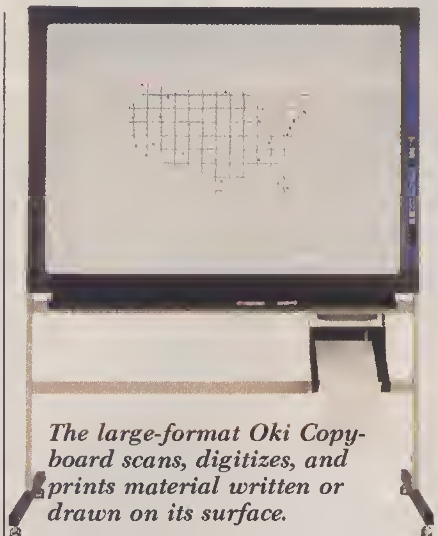
NASA joins drought relief effort

Organizations searching for water in drought-stricken regions of Africa have enlisted the aid of a powerful resource: the Space Shuttle. Sometime soon, possibly as early as November, shuttle astronauts will use NASA's sophisticated large-format camera (LFC) to take high-resolution photographs of the Sudan, Somalia, and Ethiopia. Afterward the Agency for International Development, the New TransCentury Foundation, and similar organizations will study the photos for drainage patterns that indicate where water collects either above or below ground.

The photos will also help guide relief workers to villages in unmapped areas. Because of its large coverage (25,000 square miles per picture) and high resolution (10 meters), the LFC will provide a more comprehensive as well as a more detailed view of the afflicted regions than could be practically obtained by any other means, according to Peter Hofman, executive VP of BCI Geonetics (Laconia, N.H.), a water prospecting firm under contract to New TransCentury.

The NASA camera, developed by Itek (Lexington, Mass.), flew on the shuttle for the first time last October. Originally, it was not scheduled to fly again until 1987, according to Bruten Schardt, NASA's LFC program manager. But at TransCentury's urging, NASA decided in May to relaunch the camera as soon as possible.



The large-format Oki Copyboard scans, digitizes, and prints material written or drawn on its surface.

Blackboard makes paper copies

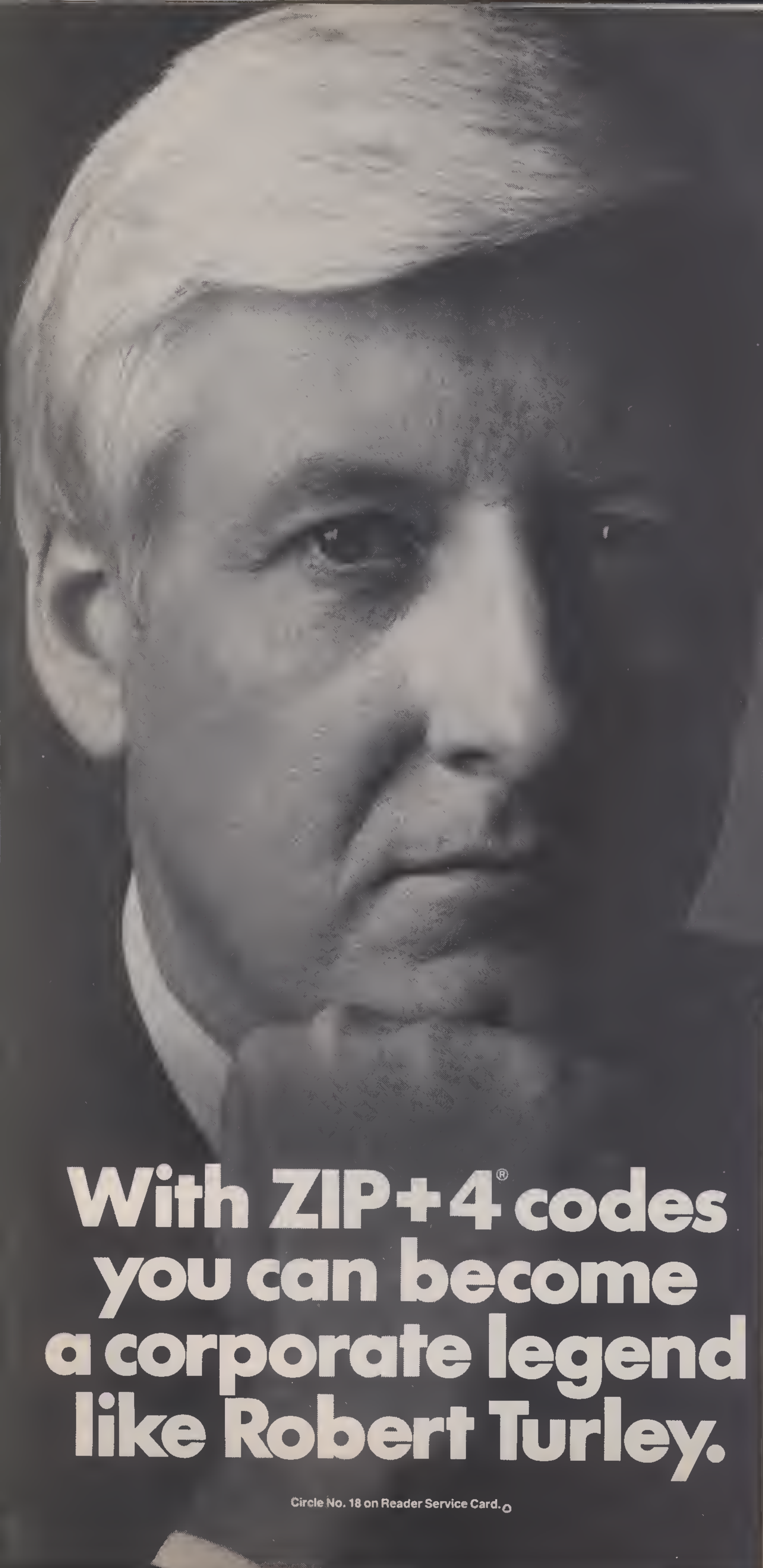
Audiences at lectures and sales presentations often spend more time scribbling down information from the blackboard than listening to the speaker. But now there's a blackboard that can do the copying *for* them. The Oki Copyboard, from Okidata Office Products (Mount Laurel, N.J.), combines a digital scanning device and a thermal printer to make paper copies of anything written or drawn on its surface. So far, says Okidata, customers include businesses, government agencies, educational institutions, and sports clubs (such as the Philadephia Eagles football team, which has recruited the board for strategy sessions). The Copyboard comes in two versions: a 51 × 36–inch model ($3495) with four separate writing surfaces and a 34 × 25–inch model ($2795) with two. To change writing surfaces, the user simply scrolls from one to the next.

As the surface scrolls into the unit, it is illuminated by a high-frequency fluorescent light. The reflected light is directed to a charge-coupled device (a solid-state optical sensor), which converts the light into digital pulses. A comparator then measures the pulse voltages against a reference voltage to determine whether a given point has a mark. The Copyboard has a scanning resolution of about 1.35 dots per millimeter vertically and 1.35 lines per millimeter horizontally. Producing one 8½ × 11–inch page every 10 seconds, the printer makes copies with a resolution of six dots per millimeter.

In addition to the sophisticated electronics, one of the board's key technical innovations is less glamorous: a proprietary writing surface that won't smear when erased.

Player piano music enters the computer age

Q-R-S Music Rolls (Buffalo, N.Y.), a manufacturer of player piano rolls for 85 years, has converted its store of over 10,000 selections—including live performances by Scott Joplin, Fats Waller, and George Gershwin—into digital signals recorded on floppy disks. A hardware interface enables two popular microcomputers (the Commodore 64/128 and the Apple IIc) to play these disks through the sound generation systems of one or more electronic keyboards equipped with MIDI (Musical Instrument Digital Interface). MIDI, a standard hardware/software system that lets electronic instruments communicate with one another and with micros, was formerly found only in professional instruments. But it's now becoming widely available in home organs and low-cost synthesizers.



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If there's a Holy Grail in scientific computing, it's speed. No engineer likes waiting for days to learn how a modified airplane wing, for instance, performs in a simulated wind tunnel test. Yet as soon as a faster machine comes out, researchers design more complicated simulations. And so the spiral grows, held back only by comparably expanding price tags for new hardware (today's top-of-the-line supercomputers can ring in at more than $10 million).

One cost-cutting alternative—adopted by a number of new manufacturers, including Sequent, Encore, Elxsi, and now three-year-old Alliant Computer Systems (Acton, Mass.)—is to harness together inexpensive off-the-shelf microprocessors to approach the output of big, high-priced machines. Alliant's FX/8, introduced in July, contains as many as 20 processors and applies a variety of speedup techniques. Its computational processors, of which there are from one to eight, can each perform "vector processing" (the method supercomputers use for number crunching) to do calculations on groups of numbers rather than one number at a time. But in contrast to supercomputers, which need special vectorizing software, the FX/8 automatically converts software in Fortran (by far the most popular scientific programming language) into a vectorized format. The FX/8 also has from one to twelve "interactive" processors, which prevent potential bottlenecks by dividing up noncomputational tasks.

Where Alliant claims the FX/8 departs from most of its competition, however, is in the speedup technique that automatically divides some of a program's routines and parcels out fragments to be done—in parallel—by several computational processors. Overseeing the delicate timing (making sure that fragments dependent on each other occur in the right order) are proprietary chips, one for each processor, that are constantly in touch with each other. These chips can, for example, stop a processor midway through a routine until its neighbor supplies a required variable.

Alliant is positioning the FX/8 (priced from $270,000 to $1 million) as a more powerful alternative to the Digital Equipment Corp. (DEC) and Data General (DG) machines that have traditionally dominated this market, says president Ronald Gruner, who anticipates that customers will include oil companies, big industrial research labs, and universities. "The leading minicomputer companies have become preoccupied with office automation," Gruner contends, and in the process have "neglected scientific computing." Alliant hopes to capitalize on this perceived opportunity by making it easy for DEC and DG customers to use their software on the FX/8; Gruner claims that Fortran programs written for other computers can be recompiled by the FX/8 to run with little or no reprogramming.

Swanson Analysis Systems (Houston, Pa.) supports this contention. Transferring its program for finite element analysis required "virtually no modification," says John A. Swanson, president of the independent software house whose customers run the program on hardware ranging from workstations made by Apollo and DEC to the top-of-the-line supercomputer made by Cray. "We had to switch one line of code out of close to 175,000," he reports. Although at press time Swanson's staff hadn't finished analyzing its test data, he estimated that the program would run at least 20 times faster on the fully expanded FX/8 than on DEC's popular VAX-11/780. Such "clearly superior" performance will be essential to winning customers away from DEC and DG, says Swanson, but doesn't by itself guarantee success. More important in the long run is Alliant's ability to convince software vendors to transfer the bulk of their programs to the FX/8. "Technical capability is just one factor in whether or not a computer will sell," he says. "People want a machine that gives software choices."

One part of Alliant's marketing strategy—selling through other computer manufacturers—may be especially helpful in attracting application software. Gruner reports that he has been negotiating with several engineering workstation makers. And according to Marcia Brooks, an analyst for market research firm International Data Corp. (Framingham, Mass.), deals should materialize soon. She

By harnessing as many as twenty microprocessors, Alliant's new computer speeds up operation of scientific programs, claims president Ronald Gruner.

CAROL LEE

terms the Alliant system "a very strong entry" into the scientific computing market and "of particular significance to workstation companies like Apollo" as a numerical calculation engine for their computer-aided design and engineering networks.

Critics caution, though, that some users seeking dramatically faster computing may be in for disappointment. Speedup will vary with each program, acknowledges Craig Mundie, Alliant's VP of product development, depending on how much "inherent parallelism it contains of the type we deal with." Nevertheless, he contends that most scientific and engineering programs will speed up noticeably and that the growing complexity of technical programs will further increase the number of potential customers for powerful scientific computers. Privately owned Alliant, with $15 million in venture capital from firms including Hambrecht & Quist, Kleiner Perkins Caufield and Byers, and Venrock Associates, believes it can make a serious attempt at capturing a significant piece of the market.—***Sarah Glazer***

AT&T:

EASING INTO ELECTRICAL ENGINEERING

One of the fastest-growing parts of the electronics industry is the production of computer-aided design and engineering (CAD/CAE) systems for integrated circuits and printed circuit boards. Dataquest (San Jose, Cal.) estimates that market penetration is currently less than 7% and that sales ($790 million last year) should grow 47% annually through 1989. The potential rewards of this large market have lured such heavyweight entrants as General Electric, IBM, Schlumberger, Hewlett-Packard, and Tektronix. And now telecommunications mammoth AT&T—despite its still unproven record as a computer vendor—has entered the fray.

Last April, AT&T purchased part of Omnicad, a Rochester, N.Y., developer of CAD software, and in June it announced two systems consisting of AT&T personal computers and Omnicad software for printed circuit board layout. So far, though, the systems have made barely a ripple in a pool of similar products. "It's hard to get noticed with a PC-based circuit-board layout system, even if you are AT&T," says Andrew S. Rappaport, president of the Technology Research Group (TRG—Boston). He rates the two systems as technically solid but unoriginal.

AT&T's Don R. Anselmo demonstrates the company's new CAD system (which produced the circuit layout behind him).

What's generating real excitement is the possibility that AT&T will market some of the sophisticated CAD/CAE tools it uses internally. Developed by researchers at Bell Labs, these systems are reputedly among the world's most advanced—"way above what's on the market today," declares a former Bell Labs employee now working for a CAE start-up. Don R. Anselmo, a director of AT&T's Computer Systems Division, reports that the company is currently evaluating the market potential of its CAD/CAE tools but is still undecided about which, if any, it will introduce to the public.

Some observers believe that AT&T's hesitation may result from its appreciation of how difficult it is to make commercial products out of in-house systems. "There's hardly a case where internal tools have been successful in the commercial market," says TRG's Rappaport. Most internal systems lack the thorough instruction manuals and easy-to-use software features that are sales prerequisites for even the most technically advanced CAD/CAE products. And tools developed for a specific design staff working on a single company's product line may be too idiosyncratic for the open market. Rappaport conjectures that such reasoning may have been what convinced IBM—another CAD/CAE vendor reputed to have very advanced internal tools—to license software from its eventual competitors when it entered the CAD market.

Another potential stumbling block is AT&T's lack of experience in the electrical engineering market. Selling CAD/CAE systems is a far cry from selling telecommunications services to consumers and businesses, asserts Beth Tucker, an analyst for Dataquest. "This is a software-driven industry," she says—a sector with a very different style of customer support from either the service or hardware industries that are AT&T's strongholds. AT&T's Anselmo, while acknowledging the company's inexperience in the CAD market, says that Omnicad should help provide insight. Yet to skeptics, tiny Omnicad, with 1984 sales of less than $5 million, seems an odd choice of mentor for a company worth $33 billion. Acquiring one of the market leaders, such as floundering Valid Logic Systems (among the top three CAE companies), would have been more plausible, declares one onlooker. Anselmo insists, however, that the Omnicad investment was ideal. "We were looking for a catalyst for our efforts," he says, not a vehicle to provide quick market dominance.—***Alden Hayashi***

Nuclear Metals:

IMPROVING HIP AND KNEE IMPLANTS

Of the estimated 200,000 hip and knee implant operations that take place in the United States every year, about 10% involve prosthetic devices that have a porous coating of baked-on metal powder. Many doctors believe that new bone tissue adheres faster and more permanently to im-

John Nicholson of Nuclear Metals shows hip and knee implants, coated with the company's superclean metal powder. To assure purity, the powder is processed in a cleanroom (seen through the window).

WM FRANKLIN MCMAHON

plants with porous coatings than to those with smooth surfaces. In some cases, surgeons can even dispense with the cement they normally must use to encourage new tissue to adhere, permitting a much stronger "human bond" directly to the implant.

The key to success for these implants, claim the pharmaceutical houses that sell them, is the purity, uniformity, and smoothness of the particles in the metal powder coating. High-quality powder bonds better and causes fewer bodily rejections of the implants, says Larry Gustavson, manager of metallurgical research at Howmedica (Rutherford, N.J.), a division of the Pfizer Hospital Products Group. But the traditional "atomization" method of manufacturing powder—heating up metal until it liquefies and then spraying it through a nozzle—doesn't always produce a clean enough or uniform enough material.

Enter Nuclear Metals (Concord, Mass.), a $45-million-a-year company that uses a proprietary method to manufacture superclean metal powders, primarily for the aerospace and photocopier industries. The 43-year-old company, whose founders worked on the Manhattan Project during World War II (thus their interest in nuclear metals), specializes in a variety of metallurgical technologies, including powdermaking.

Over the years, Nuclear Metals developed a patented method of manufacturing metal powder: the plasma rotating electrode process, which uses a plasma torch to melt the tip of a metal electrode spinning on its longitudinal axis. As the metal liquefies, centrifugal force spins off droplets of molten metal, which solidify in midair into tiny spherical particles. As long as the speed of rotation stays constant, the particles remain relatively uniform. (Their size can be varied by speeding up or slowing down the rate of rotation.) To further ensure uniformity, the powder is collected and sifted under cleanroom conditions. Later, the metal is sintered (baked) in multiple layers onto prostheses in a vacuum furnace.

Because the powdermaking process takes place in a sealed chamber filled with helium gas, nonmetallic impurities that could later trigger implant rejections are excluded. The end product is the "purest, cleanest, and best powder out there—no question about it," declares Todd Smith, manager of materials technology at Depuy (Warsaw, Ind.), a subsidiary of the German pharmaceutical house Böhringer Mannheim. Depuy, which uses Nuclear Metals powder, is currently the only company with Food and Drug Administration approval to sell porous coated implants for use without cement.

But because several other manufacturers are also testing such implants, Nuclear Metals sees an excellent opportunity to expand its market. Thus the company has been seeking new business from pharmaceutical houses that sell implants, says John Nicholson, marketing manager for prosthetic powders. Already, he says, several potential new customers are evaluating prototype quantities of the company's powders.

Meanwhile, Nuclear Metals is experimenting with titanium alloy powder coatings for implants, because these materials cost less than the cobalt alloy it now uses. (The company's current powder, an alloy of cobalt, chromium, and molybdenum, is priced from $50 to $150 a pound depending on particle size, says Nicholson.) Staff researchers have even manufactured prototype hip and knee implants made entirely from titanium alloy powder. They form the implant using a powder metallurgy compression technique called hot isostatic pressing (developed to fabricate complex aircraft engine parts) and then add more powder for the porous coating.

Even though the totally powder-formed implants are still a long way from commercial introduction, Nuclear Metals expects prosthetics to become an increasingly important market. Last year the company's powder metal business generated $4 million in revenues, mostly from sales to the aerospace and photocopier industries. "Porous coatings," says Nicholson, "represent a small but growing part of our powder business." How rapidly it grows is out of the company's control, he adds, depending instead on how quickly more pharmaceutical houses get FDA approval for their porous-coated implants.—***Al Furst***

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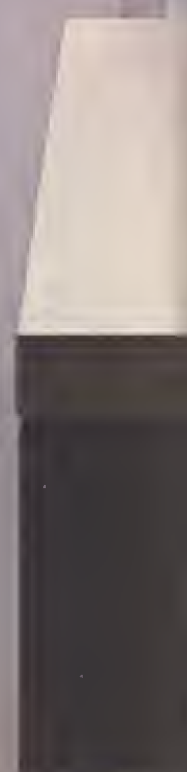

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CAMCORDERS: *HOME MOVIES MADE SIMPLE*

The camcorder—a video camera and a videocassette recorder (VCR) squeezed into a single compact package—is a technological marvel that may eventually replace film for making home movies. Several manufacturers have recently introduced camcorders in the U.S. at prices ranging from \$1400 to \$2000. But consumer acceptance will be complicated by the existence of three incompatible recording formats, which must battle it out for market dominance.

Compact video camera/recorders could be the next big consumer market

Until 1984, all conventional VCRs used half-inch-wide videotape but recorded information in two incompatible formats: Beta and VHS (Video Home System). Camcorders are already available in both of these formats. Now a few companies are introducing camcorders that use an entirely new format: 8-millimeter videotape. Because 8-mm camcorders are smaller and lighter and offer higher-quality sound, they should mount a strong challenge to the established formats.

Designing a consumer camcorder of reasonable size, weight, and cost was a major technical achievement, requiring several innovations in the recording system. In videotape recording, the key issue is the writing speed—the speed at which the tape moves past the magnetic recording or playback heads. All else being equal, the faster the writing speed, the better the quality of the video images recorded or displayed. This is because at higher speeds there is more room on the tape to record higher frequencies. (In video, the frequency governs the number of picture elements—and hence the amount of detail that can be recorded.)

by Mark Schubin

The crucial breakthrough in VCR design was the development of helical scanning, in which the videotape wraps in a U shape around a rotating drum with, in most cases, two recording/playback heads on opposite sides. The recording heads rotate at an angle to the tape and thus trace a diagonal path across its width. Because the recording heads are spinning faster than the tape is moving, the writing speed is increased with no change in tape speed. The videotape wraps around half the drum's circumference (180°), so that it is always in contact with one head but never with both. As the drum spins (at about 1800 rpm), the two heads trace alternating diagonal tracks along the tape. The two heads are placed at slightly different angles, or azimuths. That way, if one head accidentally overlaps a portion of an adjacent track during playback, the difference in angle will prevent interference.

Each half rotation of the drum records a diagonal track on the tape corresponding to one TV field. Each television image, or frame, consists of a complete set of scan lines written from top to bottom. To avoid flicker, the display rate of 30 frames per second is doubled by means of a technique called interlaced scanning. Each frame is divided into two fields, one made up of odd-numbered scan lines and the other made up of even-numbered scan lines.

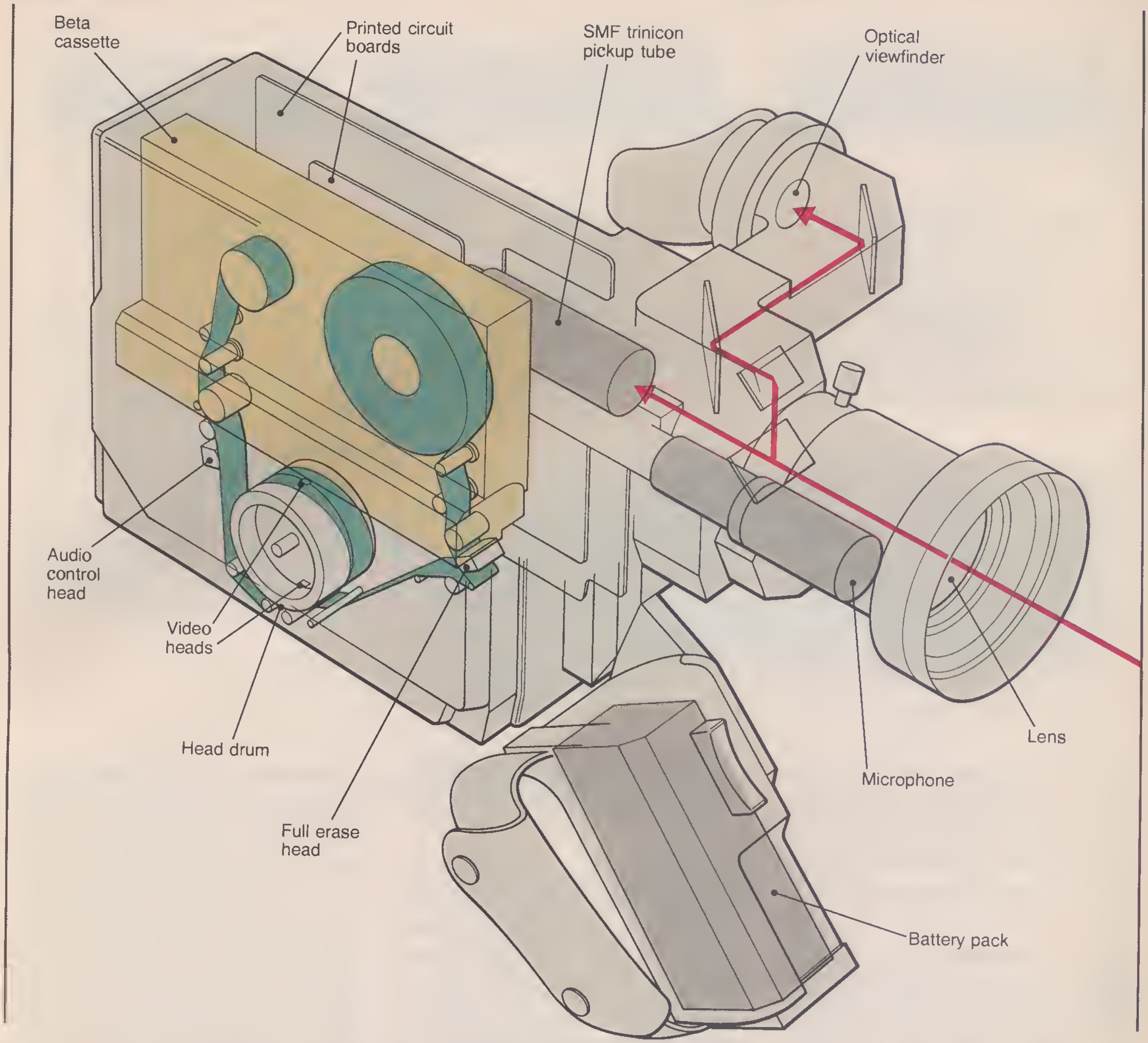
The ability of VCRs to record one field per diagonal track makes possible a number of special effects. Even when the tape is not moving, the spinning heads can trace the same video tracks repeatedly, presenting a "freeze-frame" image on the screen. And if the tape is moving slowly, the heads can switch between tracks more slowly than usual, yielding a slow-motion image.

The biggest selling point of camcorders is their compactness and light weight. Although the next generation of designs will probably incorporate smaller optical configurations and lenses made of plastic, engineers have so far concentrated on miniaturizing the VCR part of the system, particularly the head drum. Normally, a smaller drum means a lower writing speed and thus a decline in picture quality. The three camcorder formats currently on the market—Beta, VHS, and 8-mm—have solved this central problem in different ways.

Sony's Betamovie. In the fall of 1982, Sony began demonstrating aBeta-format camcorder known as Betamovie, which was introduced to the public in August 1983. Betamovie is comparable in size and weight—6½ lbs., including battery and cassette—to a super-8 film camera. Yet it uses a full-sized Beta cassette, which can record up to 3 hours and 20 minutes of video information.

Instead of reducing the size of the cassette, Sony shrank the head drum diameter from the 74.5 mm of a conventional Betamax VCR to 44.7 mm. In order to make the smaller drum compatible with standard Beta cassettes, Sony placed the two recording heads

BETAMOVIE



next to each other, instead of on opposite sides of the drum. The drum rotates at 3600 rpm—twice the standard speed—and the two heads alternately record field information with each revolution. Surprisingly, this setup yields a writing speed of 27.6 feet per second, 20% higher than that of Beta VCRs. Thus, despite the smaller head drum, Betamovie actually provides higher image quality.

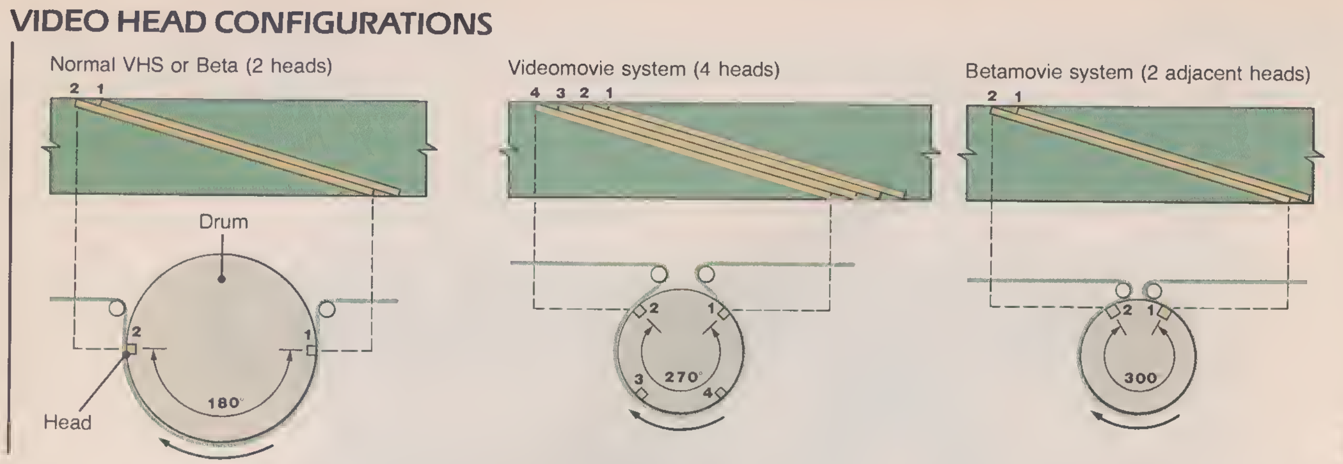
Because both recording heads are on the same side, the drum might seem to require a tape wrap of 360°, instead of the conventional 180°. Yet it's impossible to wrap the videotape completely around the drum without overlap. Sony therefore selected a 300° wrap, which provides only five sixths as much time to record a video field.

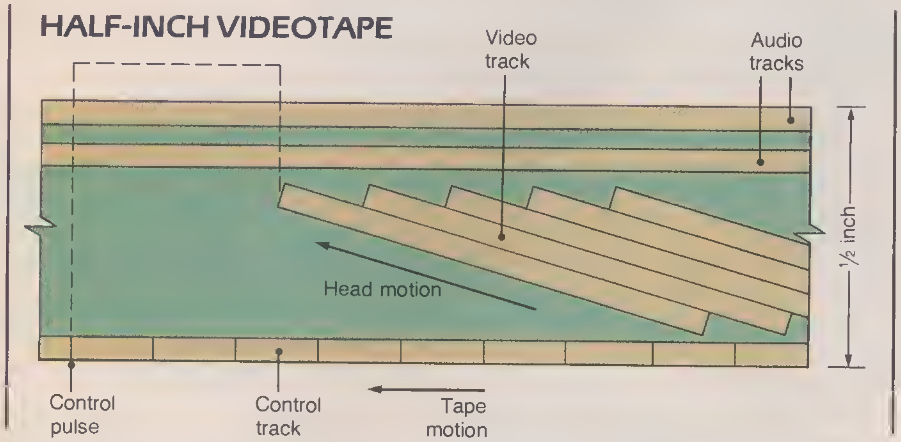
To get around the timing problem, Sony broke the most basic design rules for VCRs—but did so successfully. Conventional American TV frames consist of 525 scan lines, of which 484 appear in the picture; the unused scan lines allow time for the electron beam to travel from the bottom of the screen back to the top. The Betamovie video camera generates the same 484 active scan lines, but the total number per frame is 630 instead of 525. Each scan line is written 20% faster than usual, and each field is recorded 20% faster. Thus by the time the dual-azimuth recording head reaches the 300° point, where it loses contact with the tape, there is nothing left to be recorded but the extraneous scan lines, which are simply dropped.

Betamovie incorporates other clever innovations as well. Conventional electronic video cameras process color information and brightness, or picture, information separately and then combine them into a single signal. VCRs also record color and picture separately, and hence must reseparate the incoming video-camera signal into these two types of information. But the camera section of the Betamovie never combines the two types of signals in the first place, so they don't have to be reseparated in the recorder. This shortcut saves circuitry and reduces size, weight, and power consumption; in theory, it also reduces image degradation associated with separating and combining.

The drawback of these innovations is that the Betamovie's camera cannot be used in combination with a standard VCR. Moreover, Betamovie cannot offer instant playback, because its non-

Sony's Betamovie is the smallest camera and video recorder that takes a full-sized half-inch cassette. To save space, engineers changed the head geometry from earlier Beta-format VCRs.





***Above:** The critical space-saving measure in camcorders is a more compact recording head assembly with a wrap-around angle greater than that of normal VHS or Beta.*

***Left:** Enlarged view of recorded tracks on videotape shows diagonal video tracks and three linear tracks (two for stereo audio and one for controlling the playback synchronization).*

standard, high-speed scanning system would produce intermittent bursts of video too fast for a TV set to deal with. To view a recorded Betamovie tape, one must remove the cassette from the camcorder and insert it into a separate Beta VCR.

JVC's Videomovie. Less than a year after the introduction of Sony's Betamovie, Victor Corp of Japan (JVC) countered with a camcorder called Videomovie, which uses the VHS recording format. Videomovie weighs about five pounds (including battery and cassette), has a 41-mm drum (instead of the conventional 62-mm VHS drum), and uses VHS-C videocassettes—compact VHS cassettes that have a smaller housing and contain less tape. Unlike Sony's Betamovie, the JVC machine offers instant playback.

JVC took a very different approach from Sony to the problem of wrapping the videotape around the smaller drum. Instead of reducing the number of head positions from two to one, JVC increased them to four and used a tape wrap of 270°. When the first head finishes recording a field and is about to lose contact with the tape, the second head, 270° away, is just making contact. As the second head reaches the end of the tape wrap, the third head, again 270° away, takes over. The process continues with the fourth head, after which the first head starts over. Seen from above, the drum has four equally spaced heads that record in the order 1, 4, 3, 2 as the drum spins.

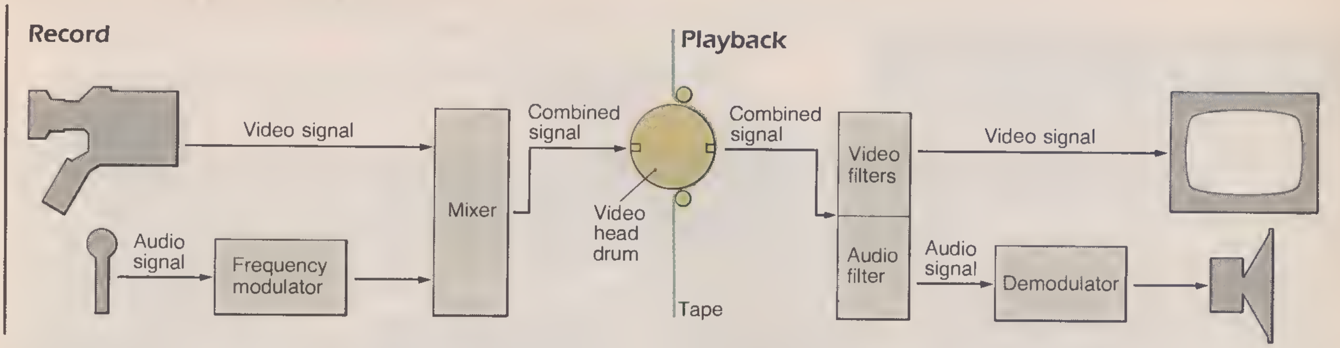
In order to be consistent with the standard VHS format, the drum speed of Videomovie had to be increased by 50% to 2700 rpm. The result is a writing speed of 19 feet per second—exactly the same as that of conventional VHS recorders. Thus Videomovie can play back just-recorded and previously recorded VHS-C cassettes, offering all of the capabilities of a conventional VCR except the ability to record or play full-sized VHS cassettes. And although current Videomovie camcorders can record just 20 minutes, some industry observers expect the introduction of a two-speed version that could record up to an hour on a VHS-C cassette.

Eight-millimeter camcorders. Between the arrival of Betamovie and Videomovie came the announcement that Eastman Kodak (Rochester, N.Y.) was entering the market with a camcorder that would use 8-mm videotape, about two-thirds the width of the half-inch tape used by both Beta and VHS recorders. The new format grew out of a March 1982 standardization conference attended by 122 video manufacturers from around the world. These companies later adopted a video-recorder standard that specified an 8-mm-wide tape in a cassette only slightly larger than an ordinary audio cassette, a drum diameter of 40 mm, and a writing speed of 12.5 feet per second. Unlike other VCRs, which record the audio signal through a separate, fixed head, 8-mm machines record audio through the spinning video heads, which provide the frequency response needed to modulate the audio signal onto an FM carrier. Consequently, the 8-mm format provides much higher sound quality than standard (non-Hi-Fi) Beta or VHS.

The small drum size used in the 8-mm format results in a slower writing speed. The designers compensated for this not by changing the configuration of the heads (an approach that had yet to be tried), but by using an improved type of videotape that is coated with metal particles rather than the metal oxide particles used in conventional tape. Because the metal particles are smaller and more densely packed, they can store much more magnetic information in the same area. Furthermore, the intensity of the magnetic signal that can be stored on metal tapes is more than twice that of the best oxide tapes, providing an improved signal-to-noise ratio (less snow in video and less hiss in audio).

Eight-millimeter camcorders also differ from half-inch VCRs in the way they ensure that the video heads on the drum

EIGHT-MILLIMETER FM AUDIO



U*nlike standard Beta and VHS camcorders, which record and play back sound with a fixed audio head, 8-mm machines use the spinning video heads, which provide sufficient frequency range for high-fidelity FM audio. In recording, the audio signal is first frequency-modulated, then mixed with the video signal. The combined audio/video signal is sent to the video heads, which record it in tracks that run diagonally along the tape. In playback, the combined signal from the video heads is sent to a bank of filters, where it is reseparated according to frequency into its video and FM audio components. Finally the audio signal is demodulated for playback through a speaker or headset.*

line up properly with the video tracks during recording and playback. In conventional VCRs, a fixed head records a control track consisting of a regular series of pulses (one pulse per frame) along the edge of the tape. During playback, these pulses enable a speed control mechanism on the tape drive or the drum to align the tape. In addition, a tracking control system compensates electronically for slight differences in the position of the control-track head on the machine that recorded the tape and the machine playing it back. The 8-mm standard omits this system entirely, replacing it with four positioning signals recorded along with the video signals on the tape. During playback, the position of the rotating drum is adjusted automatically to yield the optimum level of the four signals.

Kodak's 8-mm camcorder, known as Kodavision, is similar in size and weight to Betamovie and Videomovie (it weighs about five pounds, including battery and cassette). Manufactured by Matsushita of Japan, Kodavision uses a camera tube just a third of an inch in diameter, the smallest yet used in any TV camera. The camcorder has a built-in recording and playback capability and uses videocassettes with lengths of up to two hours. When Kodavision was introduced this past January, tapes were played back either through the camcorder's viewfinder or via a VCR-sized device called a cradle, which feeds the video signals into a TV set and functions as an interface to other video components. The cradle, designed as the system's primary playback component, can also be equipped with a tuner/timer for recording broadcast or cable programs. With these accessories, the camcorder can substitute fully for a home VCR.

Polaroid (Cambridge, Mass.) is marketing an 8-mm camcorder called Polavision. Manufactured by Toshiba of Japan, its main technical innovation is the replacement of the camera tube

S*ony's Mini-8 camcorder, which weighs barely two pounds, uses the new 8-mm videocassettes.*

with a solid-state image sensor, which makes the system more rugged and reduces weight and power consumption. Solid-state imaging also provides certain advantages in picture quality, including the avoidance of ghostlike trails following moving objects under low-light conditions, and the ability to shoot extremely bright objects without cometlike trails or fuzziness. Although solid-state imagers can have defects of their own, such as a meshlike pattern superimposed over images, improved sensors are on the way. Last year, for example, RCA introduced a broadcast video camera with a charge-coupled device (CCD) image sensor that offers dynamic resolution—the ability to discern detail in moving images—as good as film's.

This past May, Sony announced an 8-mm camcorder called Mini-8, which weighs only two pounds and features a CCD solid-state image sensor and a bright optical viewfinder. The camcorder has two tape speeds—1 or 2 cm per second—the lower of which gives it a four-hour recording capability (the writing speed stays essentially the same). The Mini-8 comes with a compact playback unit that can be used in the field to instantly monitor recordings. In addition, the fixed erase head found in conventional VCRs has been replaced with a "flying" erase head on the rotating drum. Whereas a conventional fixed head cuts across several diagonal tracks on the tape, resulting in partial erasures, the flying head can selectively erase individual fields, producing smoother cuts.

Despite 8 mm's attractions, new camcorders that use the older formats may sway consumers. Sony's Betamovie is now available in a SuperBeta version that uses an extended FM recording technique to offer clearer, more detailed pictures with no loss of compatibility with older Beta recorders. Moreover, a number of companies, including RCA, Sylvania, Magnavox, NEC, Toshiba, and Quasar and Panasonic (both owned by Matsushita), have recently introduced VHS camcorders that can handle full-sized VHS cassettes. These models can record for up to eight hours and can play the vast library of prerecorded VHS tapes right in the camcorder.

Nonetheless, 8 mm is clearly the format of the future. Limited a few months ago to a recording time of 90 minutes, 8 mm has now leapt to four hours. And whereas the first models offered only high-fidelity monaural sound, the latest ones offer digital stereo. Indeed, the 8-mm VCR that Kodak unveiled in June can record up to 24 hours of digital stereo (without pictures) on a single cassette. With capabilities that strong, 8 mm might replace not only Beta and VHS but audio cassettes as well. □

Mark Schubin is a technology consultant and writer specializing in video. He has won two Emmy Awards for his contributions to television technology.

For further information see **RESOURCES** *on page 70.*

BUSINESS OUTLOOK

Camcorders join the consumer electronics parade

Camcorders—video cameras with self-contained cassette recorders—were commercially introduced only two years ago. The market is still nascent, but the firms now offering camcorders hope that demand will eventually parallel the explosive growth of videocassette recorders (VCRs) in the early 1980s.

All camcorders available in the U.S. are manufactured by a handful of Japanese companies, including Matsushita, Sony, Victor Company of Japan (JVC), Toshiba, and Hitachi. Like VCRs, camcorders come in three mutually incompatible recording formats: Video Home System (VHS), Beta, and the new 8-millimeter. To date, virtually all VHS camcorders have been manufactured by Matsushita and sold under its Quasar and Panasonic brand names as well as through arrangements with Magnavox, Sylvania, and other companies. But now, Hitachi and JVC are beginning to produce VHS machines for RCA and Zenith, respectively. Beta systems are produced exclusively by Sony and marketed by Sony, Sanyo, NEC, and Toshiba. Sony is also in the 8-mm market, as is Canon, Polaroid (using a Toshiba machine), Kodak, and General Electric. The latter two firms are supplied by Matsushita.

The fate of camcorders—which of the systems will dominate the field, and the potential size of the market—will be tied to sales of VCRs. Typically selling for less than half the price of a camcorder, the VCR provides a logical entry for consumers into the home video market. VHS recorders command a worldwide market share of 80% and Beta machines the remainder. VHS's proportion is growing, so sales of VHS camcorders will be aided by an extensive installed base of VCRs of the same format. For Beta-format camcorders, the outlook is less rosy. "Sony's Betamovie camcorder is out of the running, and Sony knows it," says David Lachenbruch, editorial director of *Television Digest* (New York). "That's why it's switching to 8-millimeter."

Eight-millimeter camcorders have advantages that may eventually make them a formidable competitor to VHS machines. They are compact and lightweight, and they offer high-quality sound. Sony's Video 8, for example, weighs only 5 pounds (while a comparable VHS machine weighs 7–8 pounds) and provides digital audio. And Lachenbruch notes that although VCRs are only now becoming available, an 8-mm program can be copied onto a VHS or Beta tape for use in a corresponding VCR.

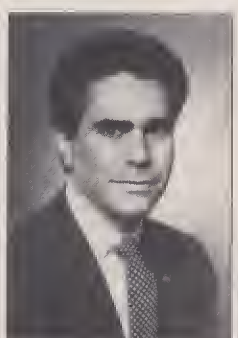
"We are exploring the use of camcorders for the business market. For example, on-site video movies could be used to enhance job training."

***Richard Lorbach, VP
Consumer Electronics Div.
Eastman Kodak***

If camcorder purchases remain linked to VCR ownership, there is ample room for growth. The Electronic Industry Association projects U.S. sales of 11.5 million VCRs in 1985, worth $4.8 billion and representing a 30% penetration level in U.S. households. Meanwhile, some 300,000 camcorders will be sold in the U.S. this year, says Donna Amrhein, senior analyst at the Yankee Group (Boston). At a price of roughly $1400, they will produce revenues of about $420 million. With prices declining to $900–$1100, she expect that 575,000 units should be sold annually by 1987, for a total of about $600 million.

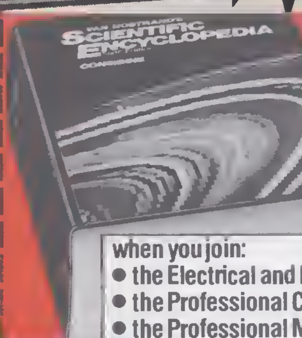
VCRs' ultimate penetration level could be 60%, according to Takashi Harino, VP at Nomura Securities International (New York), but whether the camcorder can become a mass market product depends on its price. "As an expensive item, the camcorder is more for the video hobbyist than the man in the street," he says. "If they are discounted to below $1000, their real market will become more apparent."

But how interested are people in making home movies? In their best year, film cameras sold only 1 million units, says Amrhein, even at prices way below those of camcorders. Nevertheless, the new machines may have greater appeal. Most models provide instant playback, home viewing is not dependent on unwieldy projection screens, and videotape, unlike film, can be erased and reused. Thus, says Harino, "as VCR owners come to appreciate camcorders' ease of use, a substantial market for this equipment could develop." ***—Dennis Livingston***



"The videocassette recorder acts as an educational mechanism for potential users of camcorders. Its control buttons are similar to those on camcorders, and it exposes people to the idea of using the TV set to view their own movies."

***Steve Isaacson
National Marketing Manager
Consumer Video Div.
JVC Co. of America***



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BUSINESS OUTLOOK

Camcorders join the consumer electronics parade

Camcorders—video cameras with self-contained cassette recorders—were commercially introduced only two years ago. The market is still nascent, but the firms now offering camcorders hope that demand will eventually parallel the explosive growth of videocassette recorders (VCRs) in the early 1980s.

All camcorders available in the U.S. are manufactured by a handful of Japanese companies, including Matsushita, Sony, Victor Company of Japan (JVC), Toshiba, and Hitachi. Like VCRs, camcorders come in three mutually incompatible recording formats: Video Home System (VHS), Beta, and the new 8-millimeter. To date, virtually all VHS camcorders have been manufactured by Matsushita and sold under its Quasar and Panasonic brand names as well as through arrangements with Magnavox, Sylvania, a
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chine weighs 7–8 pounds) and provides digital audio. And Lachenbruch notes that although VCRs are only now becoming available, an 8-mm program can be copied onto a VHS or Beta tape for use in a corresponding VCR.

If camcorder purchases remain linked to VCR ownership, there is ample room for growth. The Electronic Industry Association projects U.S. sales of 11.5 million VCRs in 1985, worth $4.8 billion and representing a 30% penetration level in U.S. households. Meanwhile, some 300,000 camcorders will be sold in the U.S. this year, says Donna Amrhein, senior analyst at the Yankee Group (Bos-

"We are exploring the use of camcorders for the business market. For example, on-site video movies could be used to enhance job training."

Richard Lorbach, VP Consumer Electronics Div. Eastman Kodak

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DIGITAL SIGNAL PROCESSORS

by Rick Cook

Business is booming for high-speed chips used in communications, graphics, and TV

In the midst of all the recent gloom and doom in the semiconductor business, there is one bright spot. Sales of digital signal processor (DSP) chips—specialized high-speed microprocessors designed to handle real-time digital data—are setting records. Estimated world sales this year are $60 million, projected to grow to over $500 million by the end of the decade, according to industry analysts at Forward Concepts (Tempe, Ariz.).

Digital signal processing isn't new. NASA has long used it to enhance space probe pictures, for example, and the military has used it to boost the efficiency of radar and sonar systems. What is new is the advent of relatively inexpensive single-chip digital signal processors to replace the complex and expensive printed circuit boards needed in the past. The new chips are showing up in high-speed modems, sophisticated graphics systems, robots, and speech synthesizers. According to a recent study by Mackintosh International (Saratoga, Cal.), the biggest market for DSP chips for the rest of this decade will be in data and voice communications. Later, graphics will become more important, and in the 1990s more and more DSP chips will show up in consumer products such as television receivers.

Texas Instruments (Dallas) has become the market leader, with its TMS320 family of single-chip signal processors. Other major vendors include Advanced Micro Devices (Sunnyvale, Cal.), National Semiconductor (Santa Clara, Cal.), and TRW (San Diego). Japan's NEC and Fujitsu also offer a number of digital signal processing devices. AT&T Technologies (Greensboro, N.C), formerly Western Electric, has considerable experience in manufacturing DSP chips for telephone systems and has recently begun to sell its wares in the open market.

The DSP chips of a few years ago would have been inadequate for many of the applications in which their successors are used today. Until recently, the only semiconductor technology with sufficient speed was bipolar, but bipolar chips used too much power and couldn't be fabricated in the complex designs required. Now, improvements in CMOS (complementary metal oxide semiconductor) technology have made high-performance DSP chips feasible.

The first DSP chips, introduced in 1979 by Western Electric (then the manufacturing arm of the Bell System) and AMI in Santa Clara (now Gould-AMI), got a mixed reception. Western Electric's units have been widely used in specially designed digital switches for the Bell System long-distance network. AMI's more general-purpose devices were unsuccessful because, according to company officials, potential customers didn't know how to use them.

But in the last two or three years, DSP chips and their users have become considerably more sophisticated. The devices are faster and include more hardware functions. What's more, "people are gaining knowledge of the algorithms and techniques of digital signal processing in much the same way they learned to use single-chip microprocessors six or eight years ago," says Frank Toth, marketing manager for the DSP division of Integrated Device Technology (Santa Clara, Cal.).

Although a digital signal processing chip is a specialized microprocessor, most of

For TV sets, digital signal processing will provide clearer pictures (by removing noise) and allow viewers to split the screen or freeze the image.

the new generation of DSP devices have about as much in common with the processor in a home computer as a Formula One racing car has with a family sedan. Like the racing car, a DSP chip is faster and is often carefully tailored for specific tasks. And it's more expensive. For example, TI's TMS320 costs around $40 each in lots of 1000. By contrast, the Intel 8088 microprocessor used in the IBM Personal Computer can be bought singly for about $10 or in large quantities for even less.

Part of the cost difference is due to lower production volumes; even the most popular DSP chips aren't made in the same quantities as successful microprocessors. Much of the difference, though, is due to the high speed and complex hardware functions DSP chips need to do their job. For example, the TMS320 has separate memories for data and programs so that instructions can be executed while data are being retrieved. This feature increases speed but necessitates a more complex design architecture. Similarly, the NEC 7281 graphics processor uses a highly parallel architecture for faster execution of instructions. But while DSP chips are more expensive than other microprocessors, they are a lot cheaper than conventional board-level designs.

Despite the complexity of the chips, the idea of digital signal processing is fairly simple. An electrical signal, such as that generated by the human voice through a microphone, is translated into a series of numbers that can then be manipulated at high speed by a computer in the same way as any other numbers. In speech processing, for example, a voice signal may be sampled and split into anywhere from 8 to 20 frequency ranges, each processed separately. Multiplying all the signal sample values by a constant amplifies the signal. Multiplying the sample values in just part of the frequency spectrum is equivalent to putting the signal through a filter.

Amplifiers and filters are more commonly built as analog devices—sets of components that work directly on the signal instead of on a digital representation. Analog signal processing is a well-developed technology and generally cheaper where it is applicable. However, DSP can be set up or reprogrammed more easily, does not require frequent readjustment for component aging and drift, and is much better at handling very high or very low frequencies. "With the signal processing algorithms we are using, it would be extremely difficult to create analog filters to do the equivalent processing," says Steve Love, a software engineer for Votan (Fremont, Cal.), a manufacturer of speech recognition systems. "You could do it, but things would be touchy, unstable, and extremely component-sensitive."

As with conventional microprocessors, programmability makes DSP chips remarkably versatile. Designers can put the same device into a modem, an image enhancer, or an artificial ear, just by developing a suitable program. They can also fine-tune the chip to an application by modifying its programming at the prototype stage. Fine-tuning an analog signal processor or a board-level digital processor often means redesigning the entire circuit.

In addition, a DSP chip is fast enough that it can be programmed to adapt in real time to shifting circuit conditions. This capability is particularly important for voice and data communications. Echo cancellation circuits, for example, must be able to adjust telephone repeaters to constantly changing line characteristics.

The reason DSP chips are so much faster than conventional microproces-

How digital signal processing works

Most electrical signals are analog—the waveforms generated by telephones, TV cameras, or radars, for example, vary continuously over time. To be processed digitally, such signals must be digitized, or converted to discrete, on/off pulses. The digitized signals can then be manipulated by a digital signal processor (DSP) in the same way binary numbers are operated on by a conventional microprocessor. After processing, the digital signals must generally be converted back into an analog form.

Because digital signal processors are programmable, their range of applications is extremely broad. Three typical DSP applications illustrate this versatility:

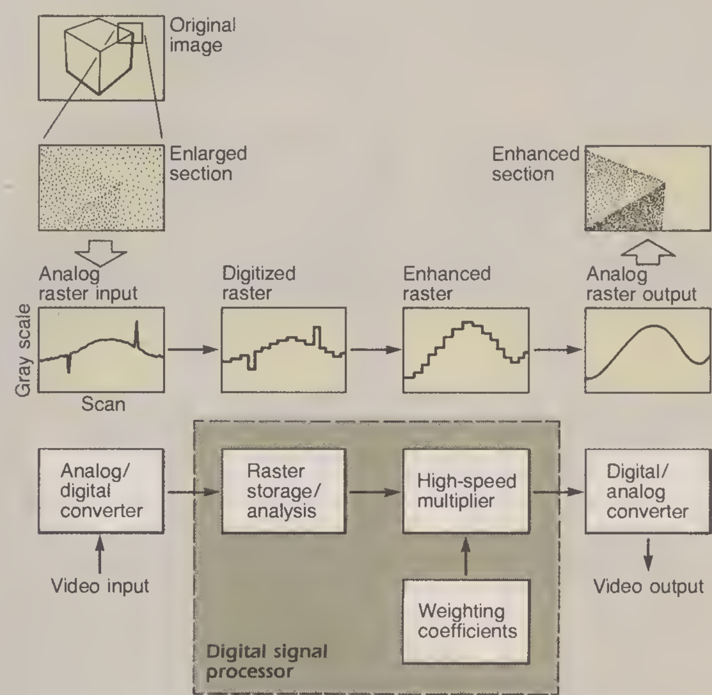
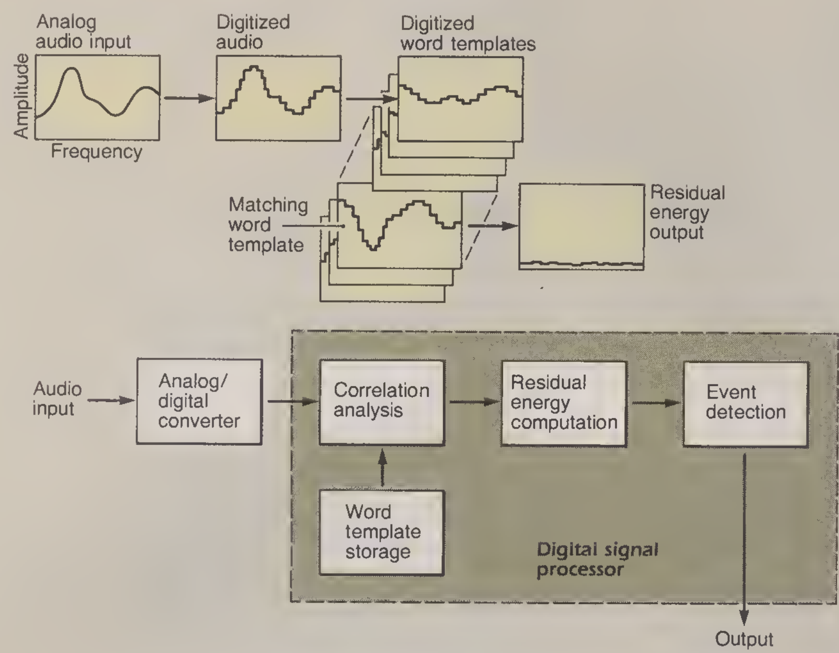


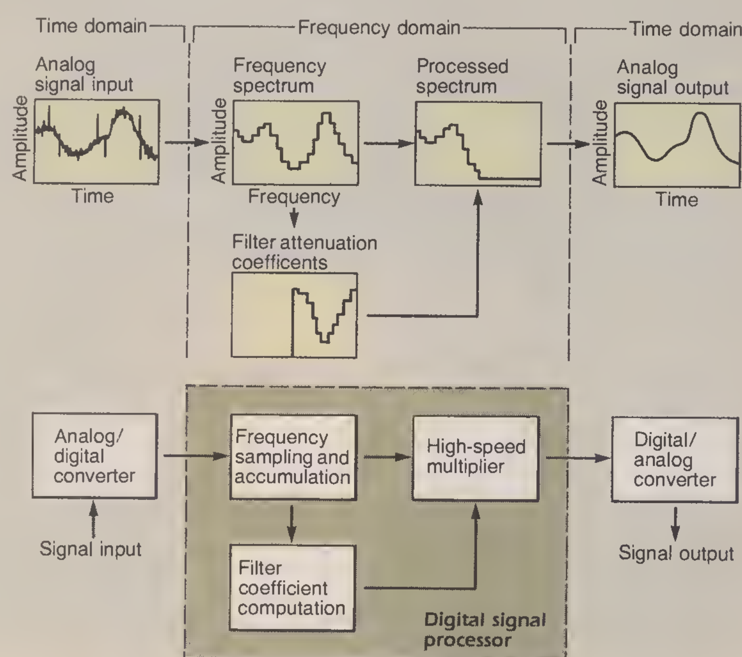
Image enhancement

This application may take several forms, such as removing "snow" from a TV picture or increasing the contrast of a picture to render greater detail. NASA has used digital signal processing to enhance the TV transmissions of satellite photographs of Saturn and Mars (see photo, p. 28). In the simplest (raster) method, the picture is scanned by a TV camera, with each line producing an analog signal corresponding to the tones of the original scene. This signal is digitized by an analog-to-digital converter and stored by the DSP. Each picture element in the scan is compared with its neighbor so that aberrations due to noise can be removed and weighting coefficients can be applied to increase the range of the gray-scale values. Finally the enhanced set of elements is converted to analog form. The result: a more detailed picture.



Speech recognition

In a scheme developed for Texas Instruments' TMS320 DSP chip, the signal processor compares an incoming signal against the inverted digital images of more than 40 word templates stored in memory. A match is found when the residual difference signal is nearly zero. (A dynamic programming algorithm allows a match to be found even if the spoken word is uttered at a different speed than the stored word.) An event detector then outputs commands—say, to initiate the appropriate computer operation.



Adaptive filtering

Digital signal processors can take the form of filters that respond adaptively to changing line conditions. For example, the echo produced when telephone signals are reflected back along the line can be canceled in real time by DSP. The echo pattern is identified, and a negative version of it is constructed and then applied to the line signal to cancel out the echo. In the adaptive filter shown here, the analog input signal is digitized and converted into the frequency domain by a fast Fourier transform (FFT) technique. The FFT analysis is used to determine the filter coefficients required to operate on the digitized input signal to remove the high (noisy) frequencies. The filter coefficents multiply the desired elements of the incoming signal to produce a "clean" output signal in analog form.

sors is that they handle many operations in hardware rather than relying on slower software. For example, most DSP chips have built-in hardware multipliers. TI's TMS320 can do a simple 16 × 16–bit multiplication in one 200-nanosecond instruction cycle—about 150 times as fast as an Intel 8088 microprocessor.

A hardware multiplier is worthwhile because many digital signal operations consist of a series of multiplications, the products of which are then summed. To be effective, the chip has to perform such operations thousands or even tens of thousands of times each second. As simple a task as rotating a two-dimensional image on the screen of a graphics display terminal requires over a million multiplications in a thirtieth of a second (at a resolution of 1024 × 1024 pixels). For a digital signal processor, that's a relatively easy application.

A more demanding DSP application is an artificial ear, being developed at Stanford University, that contains a TMS320 chip and works by applying direct electrical stimulation to the nerves in the inner ear. First the chip acts as a filter bank, splitting the incoming sound into eight channels; then it performs 23 multiplier operations on each channel and adaptively scales the output to keep the signals within the range of the human auditory system. All this has to be repeated at a rate of 8000 times a second, the sampling rate of the analog/digital converter. The next model of the implant will use a

Digital signal processors: a high-growth market

Even in the currently bleak semiconductor market, digital signal processors (DSPs) are expected to remain a growth industry at least into the 1990s. Worldwide sales of DSP chips and related components should be $375 million this year, climbing to as much as $1 billion by 1990, according to Forward Concepts (Tempe, Ariz.). The chips themselves account for $60 million of the present market. The rest of the business is divided among conventional microprocessors and microcontrollers used in DSP applications ($175 million); building-block components, such as multipliers, which are used to produce board-level digital processors ($75 million); and specialized circuits, such as modem chips, that are not sold as digital processors but that perform DSP functions along with other tasks ($65 million).

"I don't think we are going to let the digital signal processing market slip away from the United States. Nonetheless, our Japanese competitors are powerful companies, and we do not underestimate them."

John Scarisbrick, Manager, Signal Processing, Texas Instruments

William Strauss, president of Forward Concepts, estimates that U.S. companies control 60% of the present DSP market. Japan has 35%, and Europe the remaining 5%. On the application side, 40% of all DSP components are purchased for use in military equipment, such as radar, sonar, and communications. Another 30% go into telecommunications products, and the rest are divided among consumer, industrial, and medical uses. But that mix is expected to change. "Over the next five years," says Dennis Boyce, marketing director at the consulting firm of Mackintosh International (Saratoga, Cal.), "we anticipate that the proportion of the DSP market taken up by military uses in the U.S. will decline in relative importance, although the military market itself is growing." He adds that DSP chips will find their immediate primary market in data and voice communications, with applications in speech processing, robotics, and consumer electronics becoming widespread in the 1990s.

Texas Instruments (Dallas) leads the digital chip segment of the DSP market, followed by NEC of Japan. Other major players include Advanced Micro Devices (Sunnyvale, Cal.), Intel (Santa Clara, Cal.), and Fujitsu. AT&T Technologies (New York) has significant experience manufacturing DSP chips, but has only begun to sell its products on the open market. Boyce says that "surprisingly few firms have fully committed to DSP, in part because of the dominance of military applications. Only as we see a greater penetration of DSP devices in consumer, industrial, and data processing markets will other players be attracted."

Among these new entrants will be some of the major microprocessor manufacturers, such as National Semiconductor (Santa Clara) and Motorola (Schaumburg, Ill.), which are already working on DSP chips. Several firms that do not offer merchant microprocessors are also joining the market. These include TRW (San Diego) and Honeywell (Minneapolis), which can draw on its experience in process control and its work for the Pentagon's Very High Speed Integrated Circuit program.

As the capabilities and speed of DSP chips increase, they will begin to outsell competing products and cause changes in manufacturers' strategies. For example, DSP chips will become viable alternatives to microprocessors and microcontrollers in a variety of applications, including robotic control and graphics. Moreover, the chips are encroaching on both the civilian and the low-end military markets for electronic components of board-level DSPs, which cost several times as much. ***—Rick Cook***

"Like microprocessors in this decade, digital signal processors will pervade our everyday lives in the next decade. They will be at the heart of automotive, home entertainment, and data communications systems."

William Strauss, President, Forward Concepts

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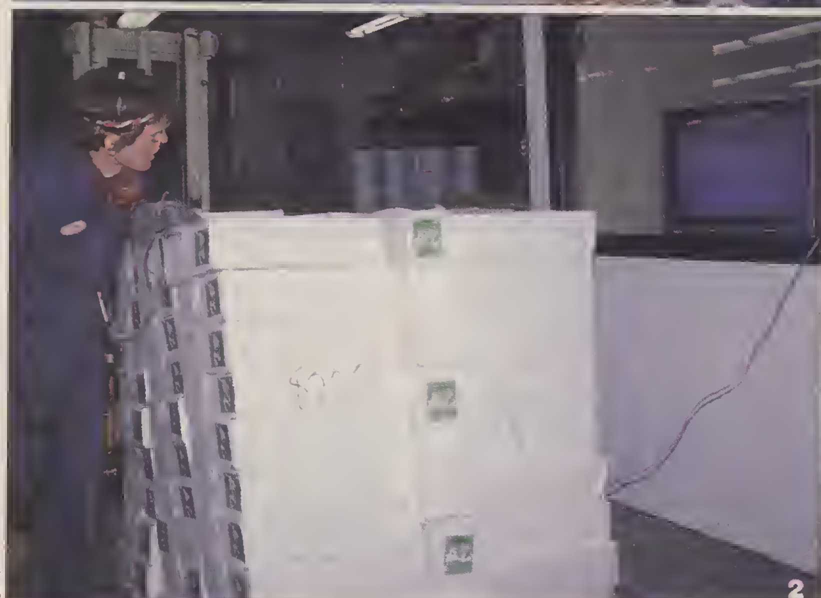

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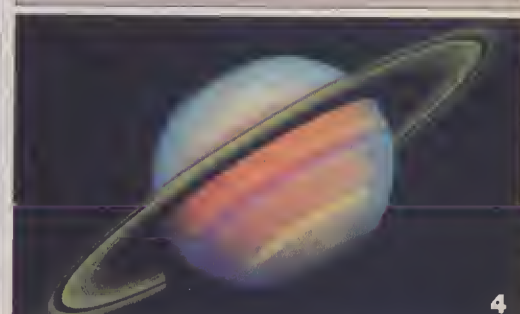


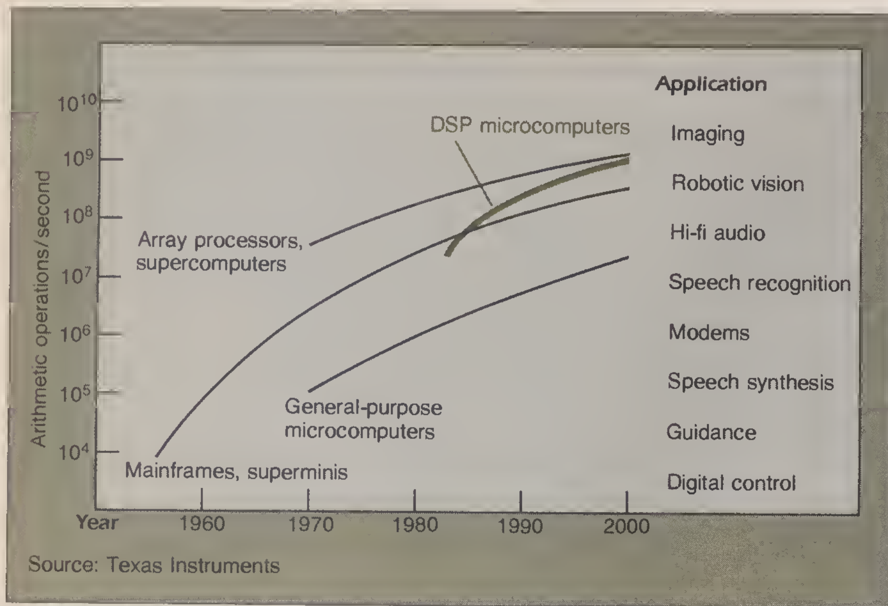
JET PROPULSION LABORATORY

1. *Teledyne Acoustic Research is developing a home stereo adaptive digital signal processor that will compensate for speaker response and room acoustics by automatic equalization.* **2.** *Votan's speech recognition system for food warehouse inventory control uses digital signal processing to filter audio signals and compensate for variations in the way words are spoken.* **3.** *High-speed modems for use on conventional switched telephone lines rely on digital signal processing to sense line conditions and adaptively equalize the modem's performance.* **4.** *Detail and color lost in the scanning and transmission of TV pictures from satellite fly-by missions to Saturn are restored by digital signal processing techniques. New signal-processing integrated circuits are extending the once expensive techniques to industrial and consumer applications.*

more sophisticated algorithm, called linear predictive coding, for better performance. That will require handling 200 multiplications per channel instead of 23 and will call for even higher-performance DSP chips.

The demand for speed in digital signal processing is so great that most high-performance DSP chips are designed with short word lengths (typically 16 bits) and fixed-point arithmetic, which make the chips fast but restrict the range of inputs and limit the precision of calculations. Some of the newest DSP designs, however, achieve greater accuracy by using floating-point arithmetic. AT&T Technologies has a new 32-bit floating-point chip, the DSP32. TRW's two-chip DSP set, the TDC 1042/TDC 1033, offers 22-bit floating-point arithmetic. More are likely to follow from other makers.

One area in which performance demands are increasing is the design of



For demanding real-time applications, digital signal processors are designed to maximize the speed of arithmetic operations by hardware execution—unlike general-purpose microcomputers, which use slower software techniques.

high-speed modems for use on regular dial-up telephone lines with personal computers. The newest 2400-bit-per-second modems have 16 possible signal states (as opposed to just two—"on" and "off"), allowing them to transmit four bits of information with each change of state. Of course, this makes them considerably more sensitive to noise than their slower predecessors. Many of these 2400-bps modems use DSP chips as adaptive equalizers (to sense line conditions and modify their signals to match) and to perform other functions as well.

The faster 4800- and 9600-bps modems will require even more signal processing. In these modems the send and receive signals overlap considerably; they will use DSPs to filter the transmitted signal so they can sense the incoming signal. The standards for these modems have been defined, and 4800-bps units are already available in Europe (see "Modem madness," p. 59).

Digital signal processors are finding particularly wide application in telephone systems as long-distance carriers move toward digitizing voice communications. AT&T Technologies and Bell Laboratories (Holmdel, N.J.) have developed a number of special-purpose DSP chips for use on the new digital networks. For example, Bell Labs' BCM3200 is a bit-compression multiplexer that removes redundancies from speech, enabling the phone company to double the capacity of a voice circuit. Other applications for DSP chips on the phone system include touch-tone detection, line performance measurement, and adaptive echo cancellation.

DSPs are expected to proliferate in computer graphics as well, especially for enhancing and manipulating images. Because film and video cameras lack the dynamic range of the human eye, gray-scale values lose detail. A digital signal processor can restore the dynamic range of an image by expanding these values, adding subtle shading. Such techniques have been used by NASA and the military for several years, but thanks to low-cost single-chip DSPs, they are now feasible for industrial and even consumer applications.

In the consumer field, the first major uses for DSPs will be in digital television. By digitizing an incoming television signal, they can manipulate the image to provide better picture quality, split screen and replay capabilities, captioning for deaf viewers, and other enhancements. West Germany's ITT Intermetall has already developed a set of special-purpose digital signal processing chips for television sets (HIGH TECHNOLOGY, April 1985, p. 28). This five-chip set is an intermediate step along the way to fully digital television. The biggest problem yet unsolved is that the bandwidth of a television signal is too large for the current generation of DSP chips to handle economically.

The rapid growth in applications is causing a major strategic split between DSP makers such as Texas Instruments, which are focusing on general-purpose processors, and companies such as AT&T and several Japanese firms, which are concentrating on special-purpose processors for each family of applications.

Probably the main reason for developing custom designs is performance. For a given application, a special-purpose DSP chip can be optimized to outperform a more general one. But there is a significant drawback: higher cost. Not only are production volumes for specialized chips lower than for general-purpose models, but new software tools must be created for each chip. To use a DSP chip, or any other microprocessor, designers need a whole battery of compilers, cross-compilers, debuggers, and other programs. It takes years to develop those tools for a chip as complex as a modern digital signal processor. In some cases, the software development costs equal or exceed the cost of developing the chip itself.

AT&T and other DSP makers think they may have a solution to these problems in the new generation of chip design and manufacturing technology. The use of advanced design systems and libraries of "cells," or predesigned components, will drastically reduce the cost of developing complex integrated circuits like DSP chips (HIGH TECHNOLOGY, June 1985, p. 18). TRW is betting on its well-developed cell library to help it fabricate specialized digital signal processors that compete against the general-purpose designs. And Bell Labs is following a similar strategy. "We think that application-specific chips will give our company a strong competitive advantage over the makers of general-purpose DSP chips," says Pat Hays, a supervisor in the company's DSP design department. "We're in the business of designing and creating telecommunications chips, and we can cooperate with system designers to determine exactly what their needs are."

Of course, not everyone agrees that custom DSP chips are the wave of the future. "I think it is an interesting approach," says John Scarisbrick, signal processing department manager at Texas Instruments. "But programming what is essentially a computer is always going to be easier than building an integrated circuit from the ground up. If a programmable device can do the job within its performance requirements, it will be the solution of choice."

Despite the design debate, the market and the range of applications for digital signal processors are expected to grow rapidly. "Many semiconductor vendors are looking at the types of chips that will save them next year," claims Forward Concepts' president, William Strauss. "Digital signal processing is the one growth area that both makers and system designers agree is going to explode."

Rick Cook is a freelance technology writer based in Phoenix.

For further information see **RESOURCES** *on page 70.*

A RENAISSANCE IN RECYCLING

JOHN TROHA

The risks and rising costs of waste disposal are stirring new interest in the recovery of materials and energy

Whatever happened to resource recovery? You remember the concept. Back in the 1970s, new technology promised to turn garbage into fuel, combustion byproducts into highway pavement, and industrial waste streams into shiny silver and gold ingots.

Despite these and other lures, resource recovery and recycling usually fell far short of their billing. For example, many of the designs were operationally unreliable and excessively complex. The result was that with a few exceptions (mostly spurred by the rapid increase in energy prices), waste recycling did not pan out as an economical or profitable business. And as quickly as new recovery designs were introduced, manufacturers found new and cheaper ways to produce virgin material.

But today, "a lot of companies see recycling and recovery as a bonanza," says Charles A. Johnson, technical director of the National Solid Wastes Management Association (Washington, D.C.). The reason is that growing environmental concerns and other influences have changed the economic equation; whereas profitability was once determined solely by the face value of the recovered materials, it is now based also on the dollar value of the disposal costs that are avoided. Those costs now run from \$25–\$40 a ton for ordinary municipal garbage hauling and disposal to hundreds of dollars a ton for certain hazardous wastes (many of which are valuable in their own right). Thanks to the new economic rules—together with a growing shortage of landfill space, rising costs of raw materials, and concern over the price and availability of strategic metals such as chromium and cobalt—recovery of a host of materials from industrial and municipal waste is at last becoming financially attractive.

by Nicholas Basta

Recovery is now being considered for nearly all manufacturing processes, and in many of them it has already become standard practice (recovery of silver from photographic and x-ray films, for example). The greatest recent strides have occurred in three areas:

- *Metal recovery.* New plasma technology, polymeric membranes, and electrochemical reactions can cull valuable compounds from slags, wastewater, or factory dusts. Other processes employ novel biotechnological methods to extract costly metals from waste streams.
- *Plastic recycling.* A virtual avalanche of old and new polymers, along with the unpredictable prices of their petrochemical feedstocks, is forcing industry to look at new methods of recycling plastics. Several techniques are under development, awaiting only economical refinements and some practical ideas about what to do with the salvage.
- *Energy from waste.* This has always been an appealing but technologically flawed idea. Modified by new and simpler methods, however, many of the original concepts are now creating a mini-industry aimed at retrieving valuable materials from trash and converting the rest into low-cost energy.

Metals from dust. Several new processes seek to isolate pure metal from industrial flue dust, wastewater solutions, or mixed-alloy scrap. The latter is a particularly important source of strategic metals—cobalt, chrome, platinum, titanium, and others—that are now imported from politically undependable sources such as South Africa and the Soviet Union.

The Swedish steelmaker SKF Steel has developed a process that uses plas-

mas (gaseous streams of charged particles) to refine dusts, scale, and scrap containing lead or zinc. The process, called Plasmadust, is now going on stream in Landskrona, Sweden, and SKF has opened an office in Avon, Conn., to pursue new business. "We have generated a considerable amount of interest here in the U.S.," says Hans Herlitz, engineering manager. "I expect that the next plant will be announced here this year."

The Plasmadust process uses baghouse dust from electric arc furnaces, blast furnaces, or other smelting operations. The metal content of the dust, of course, depends on its source. Since about 1–2% of the starting materials for these operations winds up as dust, the U.S. produces millions of tons per year of raw materials for Plasmadust—some of them rich in chrome, zinc, or other valuable metals. The fact that the dust is often a hazardous waste is another incentive for its reclamation.

At the Landskrona plant, three 6-megawatt (MW) plasma torches are mounted at the base of a shaft furnace. A recirculating reducing gas, consisting mostly of air and carbon monoxide, is turned into a plasma of up to 9000° F inside the torches. The dust is mixed with coke, slurried, and fed into the furnace. Iron and slag liquefy and drop to the bottom of the furnace for removal. Zinc and lead, which have lower melting points, vaporize and pass out the top; as they contact successively cooler regions along the path (the temperature of which can be controlled according to the metals being recovered), they condense and drop into separate chambers.

Energy recovery is a crucial factor in the process's economics. From a total energy input of about 30 MW (as electricity, coal, and coke), the Landskrona plant will generate the equivalent of 13 MW in hot water (or gas that can be burned to heat water) and 11 MW of heat contained in the hot metal streams. The hot water is used for local heating, and some of the gas can be used for preheating other steel-processing operations.

SKF wants to extend the technology to gasifying municipal garbage and treating hazardous waste with its Plasmawaste process. In this case, wastes would be vaporized in a controlled-oxygen environment. The gases could then be converted to a fuel such as synthesis gas (a mixture composed mainly of hydrogen and carbon monoxide, and sometimes small amounts of other gases). Plasmawaste is scheduled for demonstration on a semicommercial scale in Sweden in about a year, says Herlitz.

The Cryogrind freeze process is aimed at economical recycling of rubber and plastics, says Air Products' Thomas Burke.

Other metal-bearing liquid wastes come from plating, galvanizing, dipping, cleaning, and stripping operations, and from electronics manufacturing. Many of these streams contain dangerously high levels of chrome, nickel, lead, zinc, and other metals. A variety of filtration and concentration techniques are being offered for these wastes, including reverse-osmosis membranes, evaporators, and ion exchange media.

A relatively new method is the coupled-transport membrane—a microporous polymeric membrane impregnated with a chemical that attracts metal ions in solution and forms a complex with them. The complexing agent is an oil with a tertiary-amine (nitrogen compound) additive. Osmotic pressure forces the complex across the membrane to the other side, where another solution, containing sodium hydroxide, decouples the metal ion and regenerates the complexing agent.

Bend Research (Bend, Ore.), one of the leading research firms in this field, has successfully applied the technique to wastes from chrome plating. In an industrial-scale field test in 1983, metal concentrations were reduced from 300 to less than 10 parts per million, well below EPA standards.

The firm has recently licensed the technology to Consep Membranes (also in Bend), according to Dwayne Friesen, manager of Bend's metals-separation business. Consep in turn has entered into a joint venture with Bethlehem Steel aimed at installing a small-scale membrane unit at Bethlehem's Sparrows Point, Md., steel mill to treat plating wastes; the plant is scheduled for completion during early 1986. "The process has been modified to include an ion exchange operation after the initial separation," says Friesen. "The ion exchange regenerates chromic acid, which can be reused directly, from the waste stream. Previously, the product was sodium dichromate, which could not be readily reused."

Friesen adds that Bend Research is now extending the process into other kinds of metal-plating sludges, most of which end up in landfills. Disposal of these sludges, which are among the most hazardous and most intractable wastes that industry must deal with, can cost upwards of $400 a ton, according to the EPA. Bend's process would be applied to a mixed sludge, typically consisting of iron, nickel, chrome, copper, and zinc. Using a succession of separations, chemical reactions, and electrowinning (in which pure metal is deposited on an electrode), the process removes first the copper, then chrome, zinc, iron, and finally nickel. "Economics and commercial applications still have to be worked out," notes Friesen, "but we think that the process will eliminate a plating shop's disposal costs—which can run as high as $250,000 a year—while returning the value of pure metal to the plater."

Helpful microbes. Biotechnology is also figuring in metal recovery and other types of waste recycling. For example, several firms have been working with the same types of metal-plating wastes as Bend Research but employing selected organisms to recover metal. One of the more helpful of these organisms is *Ferrobacillus thiooxidans*, which can extract copper and other metals from solution through a complex series of oxidation-reduction reactions. In theory, a processor need only add the organisms to a holding pond and wait for a few weeks. The bacterial biomass is then gathered up and burned, and the metal extracted from the ash. Advanced Minerals Technology (Socorro, N.M.) and B.C. Research (Vancouver, B.C.) are among the firms investigating this approach; to date, however, researchers have not found or developed a strain of *F. thiooxidans* strong enough to withstand the harsh chemical environment of metal-plating sludges. A likely alternative approach will be to develop an economical pretreatment process that will provide the organisms with less hostile surroundings.

In a related development, former McGill University researchers in Montreal have discovered metal-chelating (binding) abilities in certain molecules that are produced by as yet undisclosed microbes. The molecules were synthesized by Irving DeVoe and Bruce Holbein, and in laboratory trials removed up to 99% of dissolved copper or other metals from waste streams.

The wastewater is run through a column (similar to a conventional ion exchange column), which contains the chelating chemical. As the waste flows through the column, the metals bind to the packing and can later be recovered. The researchers set up a firm called DeVoe Holbein (New York), and have sealed a licensing agreement with John Brown Constructors, a London-based engineering firm. The process is being developed further in John Brown laboratories, but no commercial plans have yet been announced.

Plastics and process chemistry. The steady increase in the use of plastics (especially in autos) represents another opportunity for recovery and recycling. The average 1983 car contained 209 pounds of plastic (about 7% by weight), according to General Motors. By 1990, plastics could account for 275 pounds; since the size of many cars will continue to shrink over the next five years, the plastics would then amount to 12% by weight.

The result will be a steady stream of dozens of different polymers—polyethylene, polyvinyl chloride, polycarbonates, acrylics, methyl methacrylate, and others—piling up at auto shredder plants. Because of high processing costs and poorly defined markets, these plastics (unlike automotive steel) are now considered nonrecyclable.

Under DOE's Energy Conversion and Utilization Technologies program, the Plastics Institute of America (Hoboken, N.J.) is seeking out applications for such "auto shredder residue" (ASR), which could reach almost 2 billion pounds in the 1990s. Several university contracts have been let to study ASR's composition and potential utilization, says Albert Spaak, executive director of the institute.

Tests performed to date indicate that the mixed ASR can be polymerized into a sort of composite plastic that exhibits performance characteristics well within the commercial realm. Flexural strength, for example, is shown to be in the range of 200–2000 psi, comparable to that of many structural materials such as particle board. (One potential application, says Spaak, is plastic railroad ties.) Commercialization will hinge on the development of an infrastructure for collecting, transporting, and handling the ASR—a project that Spaak predicts will be well under way within the next five years.

One technical constraint on recycling such materials is that they are useful only in the form of fine particles. A method of carrying out the necessary grinding has already been commercialized by Air Products and Chemicals (Allentown, Pa.), which originated it for processing foods—grinding spices, for example—in the early 1970s. The company's Cryogrind process uses liquid nitrogen at −300° F to freeze soft, flexible materials that could not otherwise be easily ground. After freezing (which is done through a proprietary contact process), conventional grinding reduces the size of many materials to 20 mesh (a twentieth of an inch) or finer. The company has used the process to treat a variety of plastic waste streams from manufacturers of hoses, belts, and other products made of flexible plastics. "It's important to note that this application does not always require freezing all the way down to −300°," says Thomas Burke, manager of cryogenic size reduction. "Many materials are sufficiently stiffened at much higher temperatures, which reduces the operating cost of the process."

A couple of years ago, Air Products

tried to generate interest in applying the process to recycling some of the 240 million automobile tires that are discarded annually in the U.S. Conventional grinding is complicated by the metal and fiber belts that are embedded in the vulcanized rubber. Air Products claims that the Cryogrind process will expedite the separation of metal and rubber; the powdered rubber could then be used in roofing materials, mixed in with roadbuilding filler, or broken down by pyrolysis into oil or gas.

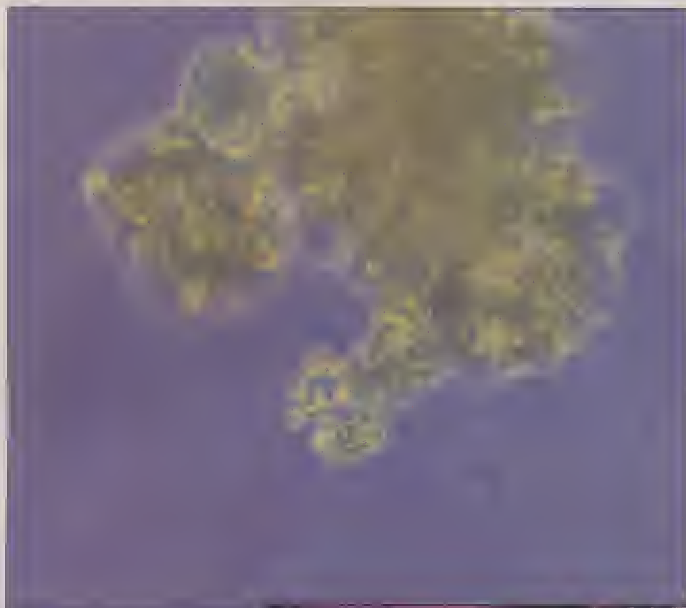
Although Air Products has signed a couple of licensees for the tire-processing application, no significant commercial activity has occurred so far. "We are ahead of the market," says Burke. But the Cryogrind process is used by a number of manufacturers of other plastic materials—elastomers and polyurethane foams, for example—especially when the plastic can be recycled into the manufacturing process directly.

Another processing route that does not require segregation of plastic types has been under development for several years by Research Services (Fort Worth, Tex.). Most polymeric fibers contain crystalline structures among the molecular chains, like the knots in a tangle of string. Many of these microcrystals can be released by acidic washing under moderate temperature and pressure, according to company president O. A. Battista. A proprietary mechanical shearing technique breaks the crystals into particles he calls suspensoids. Aqueous solutions of these particles can be applied to wires, plates, or other surfaces, then melted to form a smooth plastic coating.

Research Services contracted last year with Microtech, a Toronto venture capital firm, to build a pilot plant next year to demonstrate the technology. The goal is to use waste synthetic fiber (such as from the cutting floors of clothing manufacturers) to produce paintlike coatings that would replace films of virgin plastic. The process could also use biomass containing cellulose fiber. Because cellulose degrades before it melts, however, it couldn't be used the same way as synthetic fibers; instead, cellulose microcrystals would be marketed as a compounding agent or binder in composite materials.

Tapping our landfills. Several companies are also taking a second look at waste disposal sites as sources of energy and materials. Landfills dating from the 1950s or earlier, for example, can often be plumbed for their energy in the form of landfill gas, which usually consists of methane (50% or less), carbon dioxide, water, and small amounts of complex and possibly dangerous chemicals. The trick is to find sites with the right mix of garbage and methane-producing microbes that degrade the organic content, and then to collect the gas. Although the existence of landfill gas has been known for decades (and is a serious environmental problem in some areas), the energy price hikes of the past ten years have now made it profitable to collect.

A special strain of the bacterium F. thiooxidans *may one day be used to extract dissolved metals from waste streams.*



JOHN TROHA

A proposed use of Cryogrind is the recycling of tires, which are frozen to as low as −300° F, then finely ground.

One of the first collection projects was set up in 1979 at the giant Arthur Kill landfill on Staten Island, N.Y., by Getty Synthetic Fuels (then part of Getty Corp.). The plant generated about 1.1 million cubic feet of gas last year, most of which was upgraded to pipeline quality—that is, 900 Btu or more per cubic foot—and added to local gas-utility lines. However, the current trend is to make landfill energy more appealing by minimizing the costly and complex upgrading steps, producing a low-BTU gas instead.

To collect landfill gas, perforated pipes spaced at about every 200 feet and maintained at a partial vacuum are sunk to a depth of 40–200 feet. The gas lines are brought to a central manifold from which the gas can be treated and stored or transmitted.

The original Getty technology used inorganic chemicals called molecular-sieve adsorbents to remove water and most complex compounds; carbon dioxide was removed by an amine wash. (Both processes are widely used by natural gas producers.) Recent innovations for landfill gas involve the use of membrane separators, particularly Monsanto's Prism separators—bundles of hollow polysulfone fibers encased in a large tube. The Prism system is widely used in the chemical industry and is now being used at an Oregon landfill run by Northwest Natural Gas (Oregon City). The fibers have microporous walls that permit small molecules like methane to pass through, while larger molecules (in this case, carbon dioxide) are retained.

And in Pennsylvania's Merion Township, O'Brien Energy Systems (Downington, Pa.) is planning a landfill-gas recovery plant and power cogeneration facility. The company says it chose the site because of the quality of gas produced—about 45% methane, with little

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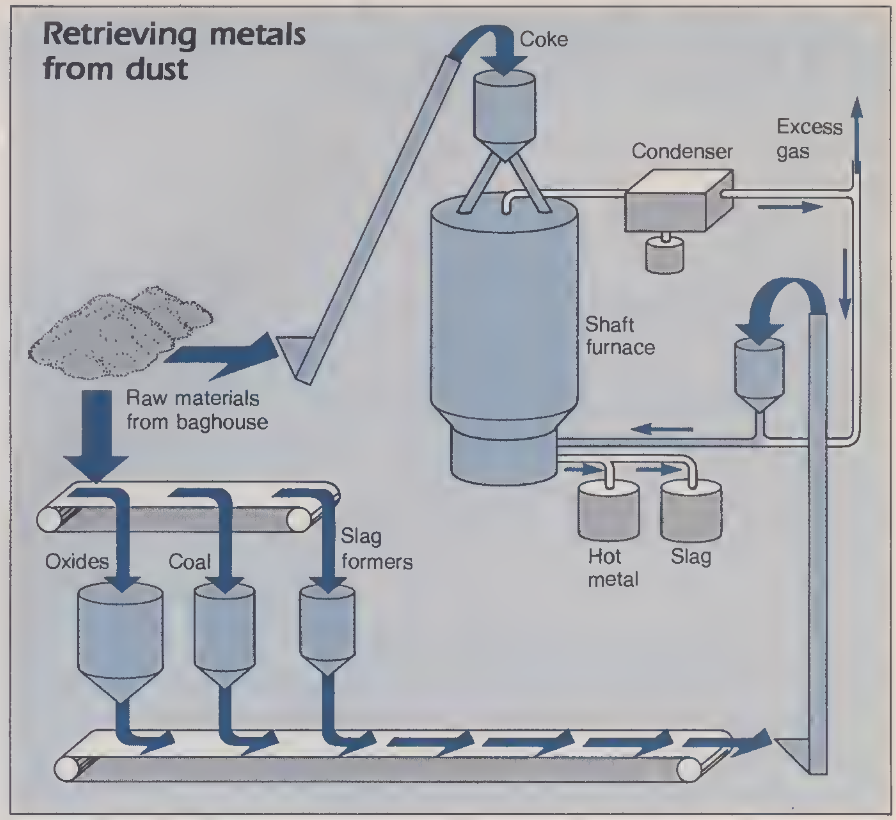
or no toxic contamination—and because a ready customer, pharmaceutical company SmithKline Beckman, is next door. O'Brien will collect the equivalent of about 20 million Btu of gas daily, pressurize it to condense and remove some water, then burn the gas directly in internal combustion engines. No other upgrading is done, leaving the product a low-Btu gas (250 Btu/cu. ft.). The engines will generate 5 MW of electricity, and cogenerated steam will heat a SmithKline laboratory building.

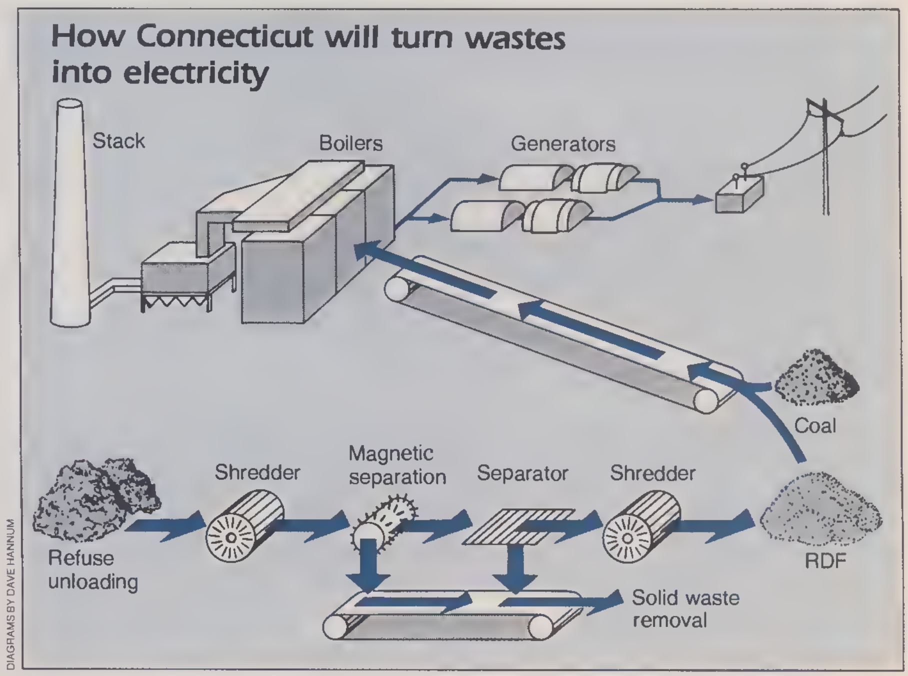
It may also be possible to convert garbage to methane-containing syngas. Many of the schemes, however, have fallen victim to spending cuts as a result of falling energy prices. For example, the Institute of Gas Technology (Chicago) has developed a process called RenuGas to generate a medium-Btu syngas composed of about 22% hydrogen, 17% carbon monoxide, 7% methane, and 2% higher hydrocarbons (the remainder being carbon and noncombustible carbon dioxide).

In the RenuGas process, waste wood or biomass is loaded into a fluidized-bed gasifier in which heat and oxygen pyrolyze the material to gas. (Fluidized beds are distinguished by the injection of gas from the bottom and the use of an inert material like sand to hold the heat in the reactor.) The RenuGas process, which runs at 1500° F and 300 psi, uses inert alumina balls to hold heat in the reactor while the gasification proceeds.

"The advantage of gasification over direct incineration is that you remove all ash and much of the sulfur from the product fuel so that it burns cleanly," says Shuresh Babu, associate director of process development. "Waste fuels like wood can be very hard on boiler equipment when burned directly." The Institute has a contract with the Department of Energy to build a 12-ton-per-day pilot unit in Chicago during the coming year.



With Plasmadust, valuable components of metalworking dusts and oxides from the shaft furnace (center) are either vaporized and condensed or liquefied out.



Several U.S. cities convert trash (about 4500 Btu/lb) to refuse-derived fuel (RDF) through shredding and separation. RDF is burned with coal to produce electricity.

Mountains of trash. Ordinary garbage (called municipal solid waste, or MSW) is again being scrutinized for its direct value, in a sort of replay of the early 1970s. Most techniques of that time sought to burn trash to create cheap energy, a dreamy idea that often turned into a logistical and engineering nightmare of costly and complex handling methods. Another problem was that some combustion products—dioxin, for example—were often more hazardous than the original waste.

The primary motive for MSW disposal today isn't energy, but the growing space shortage. "We have to figure out what to do with the 250 million tons of trash we generate in this country every year," says Johnson at the National Solid Wastes Management Association. He adds that only about 5% of it is now being recycled. "The incentive today is to simply get rid of it; if you can get some energy out of it in the process, so much the better."

Many processes aim to do both. While some of them are fairly straightforward (segregating aluminum and glass containers, for example), others are much more advanced and could result in new sources of energy, industrial chemicals, and building materials.

Basically, there are two commercially feasible ways of handling municipal solid waste: refuse-derived fuel (RDF), in

which wastes are first separated into combustibles and noncombustibles, and mass burning, which requires little or no presorting. In both cases, the combustibles are burned in on-site boilers to produce steam and/or electricity, which is then sold to utilities or nearby industrial customers. About 60 such plants are now running in the U.S.; of the 124 new ones slated to come on stream by 1990, all but about 20 are expected to use mass burning technology.

One of the few vendors sticking with RDF is Combustion Engineering (Stamford, Conn.). While early designs were hampered by costly, time-consuming precombustion sorting, such handling has now been drastically scaled back, says John Cunningham, general manager of the company's resource recovery business.

Combustion Engineering's RDF process typically consists of five steps:

1. Primary MSW shredding, which breaks up the waste and exposes noncombustibles for further processing.

2. Ferrous metal recovery with magnets; the metals, accounting for about 5% of the incoming wastes, are compacted and sold for scrap.

3. Separation, in which combustibles are segregated from noncombustibles (bone and glass, for example) by a rotary screen system.

4. Secondary shredding, which reduces the remaining materials to pieces less than an inch long.

5. Energy generation, usually by burning the shredded material in steam generators; the idea of shipping or storing the combustibles as a complement for coal and other conventional fuels has largely faded away because of costs and handling problems.

Combustion Engineering built one of the pioneer sites in Madison, Wis., in 1979. The plant has operated continuously since then, handling an average of 250 tons of MSW a day; similar plants are now being planned in Honolulu, the San Francisco Bay area, Detroit, and Hartford, Conn. The latter unit (called the Mid-Connecticut Resource Recovery Project) will be built by Combustion Engineering at a cost of $154 million, and is scheduled for completion by 1988. The anticipated 2000 tons of waste per day will be burned in steam generators, and the steam (the equivalent of 68.5 MW of electricity) will be sold to a local utility.

Modern mass burning designs are essentially updated versions of older municipal plants. However, the new units are much more efficient, thanks to higher combustion temperatures (2500° F or higher, versus 1800–2000° a decade ago). Another improvement is the use of waterwall boilers (incineration chambers surrounded by water-filled tubes). The tubes protect the walls of the boiler from overheating, while at the same time the boiler transforms the water into steam. Simple as it sounds, the technology seems to be a commercial hit: About 200 plants of both types are slated for the next 15 years, at a total cost of about $30 billion.

SIGNAL ENVIRONMENTAL SYSTEMS

This year-old plant in Peekskill, N.Y., burns 2250 tons of refuse a day to produce enough electricity for 40,000 homes.

An example of such trash-to-energy conversion is the 3000-ton-a-day unit to be built by Signal Environmental Systems (Hampton, N.H.) in New York's Brooklyn Navy Yard. The plant will be Signal's sixth in the U.S. since 1975, when a 1500-ton-a-day facility went on stream in Saugus, Mass.; other sites include Baltimore, New York's Westchester County, and Florida's Pinellas County. The Brooklyn Navy Yard unit will send its steam to the local utility for distribution in a district heating setup. A long list of vendors, including Waste Management (Oak Brook, Ill.) and Ogden (New York), are planning similar projects in Newark, N.J., Norfolk, Va., Davis County, Utah, Savannah, Ga., San Diego, Greensboro, N.C., and other sites.

Several groups are also looking at solid waste as a source of low-cost materials. The Electric Power Research Institute (EPRI—Palo Alto, Cal.), for example, has studied several ways to convert fly ash (inorganic particles generated by coal-burning utilities) into something useful or at least environmentally harmless. Fly ash recovery is widely practiced in the Soviet Union and is reportedly gathering interest among utilities in Japan.

A study completed for EPRI by Kaiser Engineers (Oakland, Cal.) found that a million tons of fly ash could yield 150,000 tons of aluminum oxide (used in some ceramics), 100,000 tons of iron oxide, 80,000 tons of alkali sulfates, and 46,000 tons of gypsum. The study was based on a process developed by Oak Ridge National Laboratory (Oak Ridge, Tenn.), in which the ash is dissolved in hydrochloric acid, then treated with an ion exchange unit. Evaporation and crystallization isolate the various streams, and a sulfuric acid treatment produces the gypsum.

A smaller effort is underway at Los Alamos National Laboratory (Los Alamos, N.M.), where researchers Thomas Meek and Rodger Blake have converted fly ash into a high-strength foamed ceramic material. Fly ash usually consists of tiny hollow spheres; treated at high temperatures, the spheres assume a lightweight, frothy structure that the researchers say could be used to produce insulating bricks. They concede, however, that the process is still in an embryonic stage.

In view of recycling's many ups and downs during the past decade, few industry observers are willing to offer firm predictions; in the final analysis, the success or failure of modern recovery techniques during any given period depends on such volatiles as energy prices, international alliances, and community endorsement.

However, most analysts agree that the long-range trend is one of growing recognition—by industry and by the general public—that many of our resources are nonrenewable and that waste dumping poses ecological hazards. In its 1982 report on recycling and waste recovery, the United Nations Environment Program spoke for business and consumers alike: "In a world of finite resources, it has become increasingly apparent that not only lifestyles but even life itself may depend eventually on the establishment of a conservation-oriented society. . . . A low- or non-waste technology is the cornerstone of this conserver society." □

Nicholas Basta is a New York–based science journalist.

For further information see **RESOURCES** *on page 70.*

Cities turn to resource recovery

Municipal solid waste (MSW)—about 78% of which is combustible—is increasingly being seen as a source of energy by cities faced with rising disposal costs, shrinking landfill space, and tightening environmental regulations. Over 60 garbage-to-energy facilities are in operation, according to Government Advisory Associates, a New York-based market research firm. An additional 200 plants—half now under design or construction, and half likely to be ordered in the 1990s—will create an engineering and equipment market worth up to $30 billion over the next 15 years, says Robert Hoguet, VP for resource recovery projects at Kidder, Peabody (New York). He expects that by the turn of the century as much as half of all municipal waste will be used in resource recovery efforts.

"Everyone wants to get away from total dependence on landfills for waste disposal. Resource recovery plants are not a panacea, but they do represent an increasingly viable option for local government and the private sector."

H. Lanier Hickman
Executive Director
Governmental Refuse Collection and Disposal Assn.

Two systems are available: mass burning and prepared fuel. "Mass burning is now the preferred technology in this country," says Norman Ritter, VP for public relations at Signal Environmental Systems (Hampton, N.H.). In this technique, garbage is incinerated with little or no preprocessing to generate electric power. Signal is a leading player, with five major projects nearing completion. Other major firms include Waste Management (Oak Brook, Ill.), Ogden (New York), Trans Energy Systems (Bellevue, Ore.), Westinghouse (Pittsburgh), and American Ref-Fuel (Houston).

In the prepared-fuel system, metals and other noncombustibles are first removed from garbage, and the remaining material is burned on-site as "refuse-derived fuel" (RDF). In its present form, such technology "has the advantages of greater thermal efficiency, lower capital costs, and less maintenance," says John Cunningham, general manager of the resource recovery division of Combustion Engineering (Stamford, Conn.). This firm is a leading purveyor of RDF plants and expects to sign up Detroit this year to build a resource recovery plant capable of handling the city's entire waste load of 3300 tons per day, making it the largest such facility in the country. Nevertheless, only 25% of the plants built or under construction use prepared fuels. The technique has an unfavorable reputation to overcome among municipal executives, since early versions were more expensive and more complex to operate than mass burners.

Refuse plant owners can count on a steady source of raw materials—about 250 million tons of municipal solid waste are generated in the U.S. each year—and some favorable economic factors. The cost of hauling, dumping, and burying garbage ranges from $25 to $40 per ton. And if space is available at all, constructing a landfill that meets environmental requirements for preventing groundwater contamination can be an expensive proposition. By contrast, a garbage-to-energy facility charges the municipality a fee closer to $25 per ton. Such a plant, using either incineration technique, can reduce the amount of waste for disposal by up to 90%, while earning income from power generation to offset the cost of construction and operation.

However, some problems loom for incinerator companies. Hoguet at Kidder, Peabody says that "some of the federal tax reforms being debated in Washington involve eliminating investment tax credits, lengthening the depreciation schedule for capital investments, and reducing the tax incentive of municipal bonds. Such moves would make the assembling of financing packages for plant construction more difficult."

The specter of air pollution, moreover, has caused controversy wherever plans for incinerating waste have been considered. Nearly all plants remove much of the dust from flue gas, and many use scrubbing equipment to reduce emissions of sulfur oxides. But dioxin, a highly toxic compound, has been found in trace quantities in incinerator exhaust stacks. Plant operators maintain that the public hazard of dioxin can be minimized by running the incinerator at a sufficiently high temperature, but this is a matter of continuing debate. ***—Nicholas Basta***

RAY ELLIS

"In principle, it might be desirable to recycle most garbage. At least through the next five years, however, no more than 25% of the waste brought to recovery plants in New York City could be economically separated out for reuse. The rest will have to be incinerated."

Benjamin Miller
Director for Public Policy
Office of Resource Recovery
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Favorable laws and tougher world markets are prompting U.S. firms to collaborate on R&D

Ever since American industry began feeling the sting of successful foreign competition, there have been calls for more cooperation among U.S. companies in developing basic technologies. A major impediment, however, was antitrust legislation aimed at preventing collusion among firms in the same industry. Now, in the wake of favorable actions by Congress and the Department of Justice, a broad spectrum of industry groups are moving to form research and development consortia. But some have already discovered that legal issues are only one of the obstacles they must overcome. Others include the difficulties of building efficient management and research teams, gaining support for projects from marketplace competitors, attracting talented researchers, and transferring technology to member firms. In the end, complying with the various antitrust statutes may seem simple by comparison.

Particularly vexing are the organizational and operational problems. U.S. firms traditionally kept to themselves any research results that might have given them a competitive advantage. "Fundamentally, companies didn't want to cooperate, and they found antitrust laws a really good reason not to," says William C. Norris, chairman and CEO of Control Data Corp. (Minneapolis). One unfortunate result of this "secretive attitude," he says, was a "shameful and needless duplication of effort."

Norris says he has long held that R&D cooperation among industrial competitors actually stimulates competition rather than reduces it, but it took mounting international competition to bring others in U.S. industry and government around to his way of thinking. Several industry consortia have recently been formed, the most famous of which is the Microelectronics and Computer Technology Corp. (Austin, Tex.), generally considered to be Norris's brainchild. MCC, which started operations in January 1983, now has 21 corporate shareholders and is pursuing four major R&D programs in its internal labs. "I tried to set up the equivalent of MCC almost 20 years ago," says Norris, "but it wasn't until a lot of these companies had the hell scared out of them by the Japanese that they were willing to give it a try." MCC's chairman, retired admiral Bobby R. Inman, concurs: "Without the spur of the Japanese competition in the marketplace, these companies would never have agreed to work together."

Antitrust action. In the same way that international competition forced industrial competitors to begin cooperating on R&D, it also prompted U.S. legislators to reevaluate the impact of decades-old antitrust laws on American competitiveness in today's global markets. Inman claims that the antitrust laws, "which were written to deal with purely a domestic market," failed to address the realities of the current economic scene. "As early as 1960," he says, "no major sector of the U.S. economy had more than 10% of its revenues in international trade. Now it's not at all uncommon for 25% of a sector's revenues to come from overseas." The laws also dealt primarily with product-

by Dwight B. Davis

POOLING INDUSTRIES' RESOURCES

related issues such as price fixing, and were therefore vague on the legality of joint R&D ventures.

Under those conditions, it was risky for companies to form any type of joint R&D venture, even if it did little more than support research programs at U.S. universities. One venture that does just this—the two-year-old Center for Advanced Television Studies—consists of five major TV broadcasters and five manufacturers of television transmission equipment. "There was definitely concern about antitrust when we formed CATS," says Kerns Powers, staff VP of government systems and communications research at RCA (Princeton, N.J.), one of the consortium's participants. "Our first meeting contained more lawyers than engineers."

ZIGY KALUZNY

To some degree, CATS considered itself on firmer ground than MCC, which, because of its in-house research approach, raised more antitrust concerns than did consortia that merely funded university projects. CATS was also able to capitalize on the legal spadework done by MCC and the Semiconductor Research Corp. (Research Triangle Park, N.C.), a 40-company consortium formed in 1982 that, like CATS, funds university research programs. Nevertheless, CATS took the precaution of requesting a Business Review Letter from the Justice Department, which evaluated the consortium for potential antitrust violations and found none.

To clarify the underlying law and remove some of the antitrust fears that plagued R&D consortia, the National Cooperative Research Act was passed by Congress and signed by President Reagan in October of last year. According to Alden Abbott, special assistant to the assistant attorney general for antitrust, the act has two basic objectives: to institute a "rule of reason" for evaluating the legality of each cooperative R&D venture on a case-by-case basis, rather than declaring it inherently ("per se") illegal; and to limit the potential liability of such consortia to actual, rather than treble, damages. Abbott explains that the act also establishes attorney fee rules that inhibit casual challenges of proposed R&D consortia. "If you lose," he says, "you will bear both your own legal expenses and those of the defending party."

Some observers believe that R&D consortia were legal even before the passage of the National Cooperative Research Act. "I wasn't greatly concerned about lawsuits even prior to the act's

ZIGY KALUZNY

MCC chairman Bobby Inman, shown relaxing at home, warns that member firms must remain vigilant in fields like wafer-scale semiconductor fabrication (top).

Representative consortia and research projects

Semiconductor Research Corp.
Box 12053, Research Triangle Park, NC 27709, (919) 549-9333

Advanced Micro Devices	Goodyear Aerospace	National Semiconductor
AT&T Technologies	GTE Laboratories	Perkin-Elmer
Burroughs	Harris	RCA
Control Data	Hewlett-Packard	Silicon Systems
Digital Equipment	Honeywell	Sperry
E. I. du Pont de Nemours	IBM	Texas Instruments
Eastman Kodak	Intel	Union Carbide
Eaton	LSI Logic	Varian Associates
GCA	Monolithic Memories	Westinghouse
General Electric	Monsanto	Xerox
General Motors	Motorola	Zilog

Objective:
To plan, promote, coordinate, sponsor, and conduct research supportive of the semiconductor industry.

Microelectronics and Computer Technology Corp.
9430 Research Blvd., Echelon Bldg. #1, Suite 200, Austin, TX 78759-6509, (512) 343-0860

Advanced Micro Devices	Eastman Kodak	Mostek
Allied	Gould	Motorola
Bell Communications Research	Harris	National Semiconductor
BMC Industries	Honeywell	NCR
Boeing	Lockheed	RCA
Control Data	Martin Marietta	Rockwell International
Digital Equipment	3M	Sperry

Objective:
To engage in advanced, long-term research and development in computer architectures, semiconductor packaging and interconnect, software technology, VLSI, and CAD.

Plastics Recycling Foundation
355 Lexington Ave., New York, NY 10017, (212) 503-0600

Allegheny Leeter-Eater	Eastman Chemical	Society of the Plastics Industry
Bev-Pak	E. I. du Pont de Nemours	Sundor Brands
Brockway	Hoover Universal	Union Carbide
Coca-Cola Bottling Co. of New York	Nelmor	U.S. Industrial Chemicals
Coca-Cola USA	Owens Illinois	Van Dorn Plastic Machinery
Conair	Pepsi-Cola	
Continental Plastic Containers	Rohm & Haas	
	Seven-Up	

Objective:
To sponsor research into improved plastics recycling, operate demonstration and research recycling facilities, disseminate recycling technology and information.

Composition of Diesel Exhaust (Research project)

American Petroleum Institute	Motor Vehicle Manufacturers Association of the U.S.
Caterpillar Tractor	National Institute for Petroleum and Energy Research
Cummins Engine	
Coordinating Research Council	
John Deere Product Engineering Center	

Objective:
To conduct research into the nature of exhaust emissions from diesel engines and develop techniques to sample, measure, and evaluate such exhaust.

Software Productivity Consortium (Proposed)

Allied	Grumman Aerospace	Rockwell
Boeing	GTE Government Systems	Science Applications Int'l
E-Systems	Lockheed Missiles & Space	TRW
Ford Aerospace	McDonnell Douglas	United Technologies
General Dynamics	Northrop	Vitro

Objective:
To explore the possible nature and structure of a joint venture to conduct research and development relating to computer software tools and techniques.

Chemical Industry Institute of Toxicology
Box 12137, Research Triangle Park, NC 27709, (919) 541-2070

Air Products & Chemicals	Monsanto
Allied	National Distillers & Chemical
Amoco Chemicals	Norchem
ARCO Chemical	Occidental Chemical
Bristol-Myers	Olin
Celanese	Phillips Chemical
Diamond Shamrock	Polysar
Dow Chemical	PPG industries
E. I. du Pont de Nemours	Procter & Gamble
Eastman Kodak	Rohm & Haas
Ethyl	Shell Chemical
Exxon Chemical	Standard Oil (Ohio)
GAF	Stauffer Chemical
General Electric	Texaco
W. R. Grace	Union Carbide
ICI Americas	Velsicol Chemical
Lubrizol	
Mobil	

Objective:
To conduct research in chemical toxicology, perform testing and disseminate results to the public, and run training programs for scientists in the field.

Center for Advanced Television Studies

ABC	NBC
Ampex	PBS
CBS	RCA
Harris	Tektronix
Home Box Office	3M

Objective:
To promote and sponsor, through independent academic institutions, research in television sciences and encourage engineering graduates to pursue careers in this area.

Test Methods for Unregulated Exhaust Emissions (Research project)

American Petroleum Institute — Coordinating Research Council

Motor Vehicle Manufacturers Association of the U.S.:

AM General	International Harvester
American Motors	MAN Truck & Bus
Chrysler	PACCAR
Ford Motor	Volkswagen of America
General Motors	Volvo North America

Objective:
To conduct research to develop, validate, and apply methods for measurement of motor vehicle exhaust emissions currently not subject to federal regulations.

Bell Communications Research

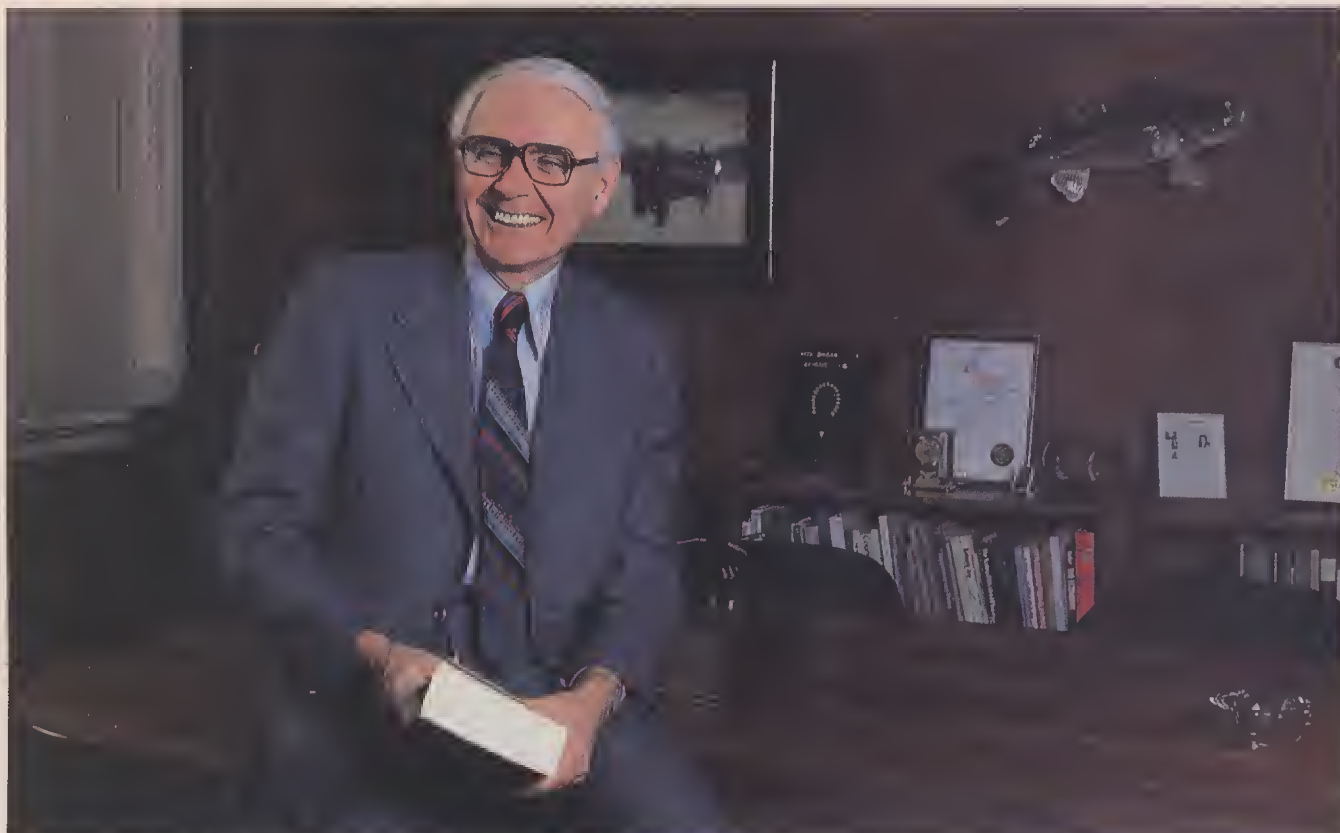
Ameritech Services	Pacific Bell
Bell Atlantic Management	Services
BellSouth Services	Southwestern Bell Telephone
NYNEX Services	Mountain States Telephone and Telegraph

Objective:
To conduct research in telephone and computer network technologies, including physical science, computer science, mathematics, and switching and transmission techniques.

Oncogen
3005 First Ave., Seattle, WA 98121, (206) 624-4300

Bristol-Myers
Genetic Systems
Syntex

Objective:
To engage in the research and development of commercial products for the diagnosis or treatment of human cancer.



JOHN MARMARAS

William Norris, CDC chairman, says international competition is forcing U.S. companies to cooperate on R&D.

passage," says Control Data's Norris, "because our cooperative ventures weren't violating any laws." One attorney on the staff of the Science Research and Technology Subcommittee of the House Committee on Science and Technology even admits that 10 years or so of court trials might have resulted in "case law coming down exactly where we did with the act." He adds, though, that "American industry would have lost a lot of time in that process." In the year since its passage, over 40 joint R&D ventures have filed with the attorney general and the Federal Trade Commission for protection under the act. "It's tough to tell how many of these ventures would have been created even if the act had not passed," says Abbott, but most believe that the legislation has stimulated joint R&D activity. "We certainly had the impression that a number of companies were sitting in the wings waiting for it to pass," says the House staffer.

Range of objectives. While many R&D consortia have formed mainly in response to international competitive pressure, other factors—such as the high cost of individual research—have also played important roles. A case in point is Oncogen (Seattle), a three-company research venture formed to help its sponsors—Genetic Systems (Seattle), Syntex (Palo Alto, Cal.), and Bristol-Meyers (New York)—develop diagnostic and therapeutic products for the treatment of cancer. "Cancer research requires a significant amount of money," says Kathryne Carr, a Genetic Systems spokesperson, "and we could not address it on our own."

Even many large companies have come to realize that they can't hope to compete individually with the well-coordinated and amply funded research of Japan and other countries. MCC, for instance, includes major firms such as Digital Equipment, Control Data, and Motorola, but none was funding the expensive and long-range research now addressed by MCC, according to Inman. And financial leverage is not the only benefit that the pooling of resources provides, he says. "MCC is a relatively inexpensive way for shareholders to put together large-scale research programs that draw talent that many of the shareholder companies, when they are candid, admit they couldn't have drawn themselves."

Fragmented and poorly funded research efforts have already hurt a number of U.S. industries, including television. In this country, broadcasters and equipment manufacturers who did research on transmission technologies acted independently and typically exerted "what we'd call 'below threshold' amounts of effort," says RCA's Powers. Yet in most other developed countries, he says, "television research is usually sponsored and directed by the governments, because most of the television organizations are government owned and operated. The net result has been that over the past several years most of the innovations in television have come from overseas."

Each of the 10 CATS sponsors contributes about $100,000 a year to the center, which currently funds student research only at MIT's Advanced Television Research Program. Because CATS has no internal research facility, says Powers, its present strategy is to profit from advance reports on the university projects and to attract more engineering students to the television profession. "One of our major objectives is to make bright young scientists recognize that television still has lots of technical challenges," says Powers. "And the hiring of students who have been trained in this area is critical for us."

One of the first R&D consortia, the Semiconductor Research Corp., was formed for many of the same reasons. SRC's main objective is to increase the amount and quality of semiconductor research at the university level. It supports more than 400 students doing research in this area, and it will be funding more than 1000 students within a couple of years, according to John J. Cox, VP of operations. "Those students will either move into the industry or stay in the universities and help

MCC research programs and sponsoring companies

Advanced Computer Architecture

Bellcore	Digital Equipment	Harris	NCR
Control Data	Eastman Kodak	Honeywell	Sperry

Packaging and Interconnect Technology

Advanced Micro Devices	Boeing	Eastman Kodak	Motorola
Allied	Control Data	Harris	Sperry
BMC Industries	Digital Equipment	Mostek	3M

Software Technology

Bellcore	Digital Equipment	Lockheed	RCA
Control Data	Harris	NCR	Rockwell
		Sperry	

VLSI/CAD

Advanced Micro Devices	Honeywell	Motorola	RCA
Control Data	Lockheed	National Semiconductor	Sperry
Gould	Martin Marietta	NCR	
Harris	Mostek		

Source: Computerworld ©

teach more students," he says.

Some of the SRC-funded research has already yielded results. A software-based simulator developed at Carnegie-Mellon University, for example, predicts the effects of variations in an integrated-circuit fabrication process on the chips' performance. "This allows the designer to incorporate protection into his design," explains Cox. "As long as the process varies within acceptable limits, he knows that his device is going to work." Another technique, developed at Stanford University, involves etching "microchannels" into the backs of integrated circuits and pumping liquid through the channels to cool the circuits. Cox says this process has permitted the use of up to 1400 watts of power per square centimeter, whereas the limit was previously assumed to be 20 watts per square centimeter. Both developments, he says, are already being used by some semiconductor manufacturers.

To further assist the student and faculty researchers, the SRC runs an Industrial Mentor program, under which academic researchers receive guidance from individuals employed by the member companies. But while the mentor program has proved highly successful, a Researchers-in-Residence program that goes a step farther—installing industry representatives at universities—has had few takers; most companies feel they cannot spare valued members of their research teams for such assignments. CATS reports similar difficulties in persuading companies to station representatives at MIT.

Quality researchers. The problem of staffing consortia goes beyond the university setting. Although many of the ventures have programs that encourage or require the member companies to contribute staff for periods of time, in most cases they have generated only a limited response. SRC, for example, has a voluntary residence program under which company researchers would serve stints of at least a year at consortium headquarters. But according to Cox, competitive pressures and limited personnel have kept most members from participating. "Since manpower is everybody's most precious resource, it's extremely hard to get people from the firms," he says.

The reluctance of shareholders to release talented researchers was especially problematic for MCC. Although the original plan had been to staff the consortium almost exclusively with personnel on assignment from the member companies, things didn't work out that way. "I got assurances that all the talent we needed could be found in the shareholder companies," recalls Inman. "But when the time came to assemble it, the quality of talent we needed just did not materialize."

Inman's response was to look elsewhere. MCC personnel now consists of about 35% shareholder representatives and 65% direct hires. From the start, says Inman, the consortium was flooded with high-quality resumes, so it had no problem finding talented people outside the member firms. As a result, he says, the shareholders started to rise to the challenge. "Gradually, as it became clear that we could fill up entirely with direct hires, some of the companies began to nominate people who were absolutely on a par with those who were applying from the outside."

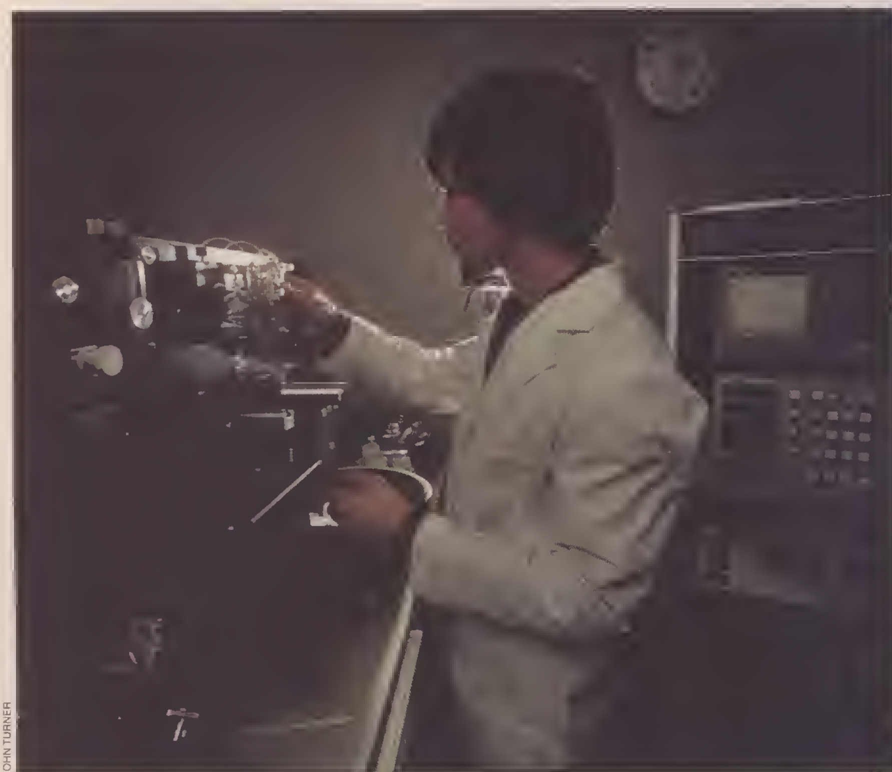
Control Data's Norris says he understands companies' reservations, especially when talented staff members are in short supply. But he claims that these firms fail to recognize one of the great merits of consortia like MCC: their highly efficient use of scarce resources. Companies get "technological leverage"—a high ratio between the price they would have to pay to develop a given technology individually and the price they pay to develop it jointly. "At MCC we're getting a technological leverage of almost ten to one," says Norris. "That means for $100,000 we can reach a technological objective that would otherwise cost us $1 million."

Consortium members also get a greater assurance that the technology developed will meet their needs and those of the marketplace. "In my experience it is very clear that participative planning of technological programs, while it might lead to slightly compromised objectives, still results in far greater insights," says Norris. "You wind up with a much better technological result when the objective is set cooperatively."

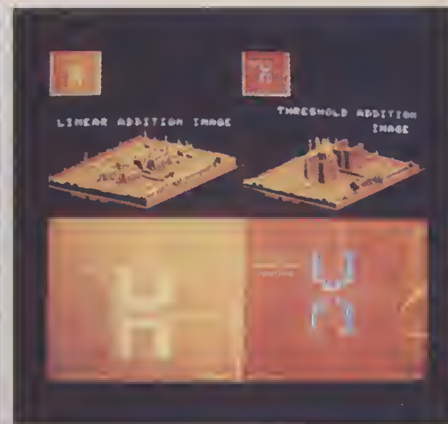
A related issue is the protection of proprietary data. Under MCC's bylaws, the shareholders have immediate access to research results only in programs they fund. (MCC has four major research programs: Software Technology, VLSI/CAD, Semiconductor Packaging, and Advanced Computer Architecture.) These shareholders have exclusive rights to any technology for up to three years after its development, after which it will be licensed to outside firms. But again, says Norris, the consternation expressed by some companies about protecting their and MCC's technology "is due to a lack of perception that there's more to gain than to lose by the broad sharing of knowledge. Given more experience with MCC, however, this virtual paranoia about the protection of technology will fade."

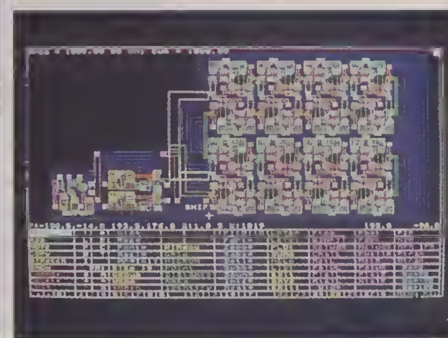
For its part, MCC has made the decision to release research results to the sponsors continually, even if the data don't yet constitute a complete, well-defined package. "A program manager may hold up on releasing research results only long enough to apply quality control," says Inman. "After that, it flows to the companies." By doing this, MCC runs the risk that it won't get credit for what's produced, but Inman believes it is a gamble that must be taken so that shareholders can exploit results faster.

That the shareholders might not exploit MCC technology fast enough is one of Inman's main concerns. By law, R&D consortia such as MCC can only perform basic research and development up to a prototype stage. They are prohibited from any manufacturing and marketing activities, so the burden of turning the new technologies into products rests with the member companies. And while Inman believes MCC shareholders are beginning to realize the importance of exploiting the technology quickly, he says U.S. firms have a less



JOHN TURNER





Three firms share expenses and technology in the cancer-research consortium Oncogen (left). The Semiconductor Research Corp. funds work such as an electron microscopy project at the University of North Carolina to perform 3-D mapping (top right) and a computer-aided design program at Carnegie-Mellon for integrated circuits (bottom right).

than impressive record in this area.

Inman, who previously served as director of Naval Intelligence and director of the National Security Agency, says one of his greatest disappointments in moving from government to industry was the discovery that, despite fewer regulations, industry is not a lot more efficient than government. "The one part of this experiment that worries me is that we might end up producing the enabling technologies two years before Japan," he says. "But unless the shareholders are far swifter at taking that technology to the marketplace than U.S. companies have been in the past, they may end up finding Japanese products getting to the market in the same timeframe."

It's therefore essential, says Inman, that shareholder firms track MCC's research programs constantly. "You never know when you're going to make your breakthroughs, and the companies must be able to respond quickly when the breakthroughs come." In fact, MCC has already produced some useful technology, says Control Data's Norris, despite the long-term nature of its research. "There is some MCC-generated technology in the area of software development tools that we're going to put to work fairly quickly," he says.

Entrepreneurial edge. If there's one type of company in the U.S. that has generally succeeded in producing innovative products quickly, it's the smaller, more flexible firms. Because such companies will continue to be an important resource, says Inman, MCC has formed an Associates Program through which they can gain access to the consortium's results. Control Data's Norris believes that providing such assistance is one of the most valuable roles R&D consortia can play—especially because research costs have ballooned recently and because government contracts, which once supported a great many small firms, have increasingly been going to large, established companies.

Norris is involved in another cooperative venture that aims to make technology available to small businesses. Called the Midwest Technology Development Institute (MTDI), the consortium is an attempt to pool the resources of 10 midwestern states. A related organization, the Midwest Technology Trading Corp. (MTTC), will be formed next year as a for-profit corporation charged with increasing the access of Midwest companies to U.S. and foreign technology.

MTDI will rely heavily on its strong base of university research facilities, in hopes of achieving greater efficiencies of research and presenting a formidable front for dealing with other countries, especially Japan. Norris contends that Japan has had very easy and low-cost access to U.S. research, and he believes that a regional consortium like MTDI may be able to exercise enough clout to remedy the situation. "Japan does not have the equivalent of the Midwest's great research universities," he says, "and a big hunk of Japan's research is done at those schools." If the universities work together to insist on more equitable treatment with respect to the use and sale of their research results, says Norris, "the Japanese would have to sit up and take notice."

Even though MTDI consists largely of university and government players, while MCC is rooted in industry, Norris foresees the two becoming more alike. He predicts that MTDI will get more involved with the business world through its association with MTTC, and MCC will gradually start supporting university research and increase its exchanges with government agencies. But while considerable progress has been made in converting skeptics to the philosophy of cooperation, says Norris, there's still an "I'll do it myself" attitude in this country that must change in order for the U.S. to compete effectively in the world market. "I strongly believe," he says, "that every industry needs at least one MCC." □

Dwight B. Davis is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES** *on page 70.*

TECHNOLOGY CENTERS UNITE INDUSTRY & ACADEMIA

New government ventures in engineering research will build on previous successes—and failures—in industry/university collaboration

When the National Science Foundation established six new Engineering Research Centers this past April, NSF Director Erich Bloch asserted that their goal was not only "to provide an essential basis for engineering research" but also "to promote strong links among universities, industry, and state governments."

Bloch enunciated these goals with confidence because of the experience that NSF has already had with joint industry/university projects. Although the new Engineering Research Centers (ERCs) are much broader in scope—as well as much better funded—than the existing projects, "NSF has what almost amounts to a boilerplate process for organizing and running industry/university centers," says psychologist Dennis Gray of North Carolina State University, who serves as an NSF-appointed monitor to evaluate progress at two such centers.

Success story. NSF draws the bulk of its experience from the Industry/University Cooperative Research Centers program, established in 1972. Initially only an experimental program, it limped along for much of the 1970s. But late in the decade, as the effects of industrial competition from overseas began to be felt more keenly, the program started to receive more attention and support. By the end of fiscal 1984, 20 centers—with a total of 250 faculty and researchers, 30 postdoctoral fellows, and 300 graduate students—had been established. At that point, funding totaled $3 million from NSF, $10 million from some 50 companies, and another $10 million from state governments. By August 1985, the number of centers had grown to 29.

by Thomas H. Maugh II

The NSF funding is awarded for a period of only five years. Grants start out large and become successively smaller each year. Then it's sink or swim: NSF provides no more money, and only the centers that have established good relations with industry and state governments survive. "The requirement that NSF get out of the centers in five years is one of the great strengths of the program," says Gray. Because the centers must ultimately get their funding from industry, he believes that they will have to be more responsive to industry's needs. "They will not be able to exert a technology push to force industry to go the way they want to. Instead, they will be subject to industry's technology *pull.*"

Five of the centers now operate without federal funding. The Polymer Processing Center at MIT, for example, has an annual budget of about $600,000 and an industrial membership that varies between eight and twelve. One of the oldest of the NSF joint centers, having been established in 1973, it is also considered one of the most successful.

The center's director, Timothy Cutowski, describes a typical project: "One of our members told us that they were having trouble molding plastics. Because a hot plastic is generally poured into a cold mold, the plastic next to the mold cools off more quickly, which produces warpage and anisotropy [irregularities in structure] that lead to structural defects. Contact lenses made this way, for example, were often distorted. When we talked about this at meetings, we found that other companies were having similar problems. One of our professors suggested that if the temperature could be controlled well enough, the problem might be solved by heating the mold."

Not only was that the solution, but the idea was commercially useful enough that several graduate students, with some help from the center's directors, formed a company to manufacture the heated molds. Intelitec (Billerica, Mass.) now sells the molds to the center's sponsors as well as to other companies. Similarly, another solution and another start-up—Axiomatics (Concord, Mass.)—evolved in response to several member companies' need for an improved way to measure moisture in

curing certain types of polymers.

Perhaps the most notable achievement of the MIT Polymer Processing Center, says Cutowski, was a project conducted in cooperation with Martin Marietta Corp., the contractor that builds and refurbishes the fuel tanks for the Space Shuttle. These tanks are covered with a rubber-based polymer that dissipates heat during the shuttle's reentry into the atmosphere. In the past, such ablative shielding had to be machined to precise tolerances, a process that was both time-consuming and expensive. But the polymer center developed several new techniques for molding various parts of the shielding that now save the government an estimated $100,000 on each shuttle launch.

Another successful program is the Center for Telecommunications at North Carolina State University. It is now in its fourth year, which means that it currently gets only $100,000 from NSF. The rest of its $1.8 million budget is provided by the university and a panel of 14 industrial sponsors that includes GTE, ITT, IBM, GE, and AT&T. The center has 14 faculty members and 26 graduate students working in six major program areas, says center codirector Siras Chipsas.

The center has already completed three major projects, Chipsas points out: a three-dimensional vision system that has been incorporated by Westinghouse into a robot that lifts heavy turbine plates, an algorithm to reduce the bandwidth of video signals sent over telephone lines (several sponsors now use the algorithm for video teleconferencing systems), and a speech-encoding algorithm that Chipsas says has great potential for improving echo control on telephone lines for voice and data transmission.

The Center for Welding Research at Ohio State University was such a success that it no longer exists! In late 1983, the state of Ohio decided to establish several technology applications centers, and after a competitive selection process, the welding center became one of them. It subsequently severed its connections to the university—although some professors still maintain some research ties—and became an independent research center called the Edison Welding Institute. The chief difference now, says former center director Carl Grace, is that it has an independent staff and performs more proprietary research and support work.

What works, what doesn't. The

DENNIS BRACK/ BLACK STAR

Erich Bloch, director of the National Science Foundation, is confident that NSF's new Engineering Research Centers will build on its previous successes with industry/university programs.

And the winners are . . .

The six schools that received funding for new Engineering Research Centers are a select group. Some 106 institutions submitted 142 proposals for new centers.

The applications were judged on four basic criteria:

- The research had to involve a team effort by individuals with diverse engineering or scientific skills. The research plan had to embody cross-disciplinary research; it could not be a collection of individual research projects.
- The proposals had to include a significant education component, involving both graduate and undergraduate students in research activities at the center.
- The centers had to focus on developing fundamental knowledge in areas critical to U.S. competitiveness in world markets.
- Research activities had to include engineers and scientists from industry and government.

The universities selected will receive a total of as much as $94.5 million over the next five years to establish and operate their centers. They include:

- The University of California at Santa Barbara, which will receive $1.17 million this year and as much as $14 million total over 5 years to establish a **Center for Robotics Systems in Microelectronics**. The center's principal objective will be to create new flexible-automation technology for manufacturing semiconductor devices and to train engineers in the implementation of robotic systems.
- Columbia University, which will receive $2.2 million this year and as much as $20 million total to create an **Engineering Research Center for Telecommunications**. The thrust of its research will be to enable the development of networks that integrate voice, data, facsimile, graphics, and video transmissions. The center will implement a flexible network test-bed to explore such integration.
- The University of Delaware at Newark, which will receive $750,000 this year and as much as $7.5 million total for a **Center for Composites Manufacturing Science and Engineering**. The center will focus on areas of fundamental research in materials science and engineering that are critical to the growth of the composites industry. An affiliate program in ceramics will be established at Rutgers University (New Brunswick, N.J.).
- The University of Maryland at College Park, which will establish a **Center on Systems Research** in conjunction with Harvard University. The schools will receive $1.5 million this year and up to $16 million total. The theme of the center will be basic research in the applications of very-large-scale integrated circuits, computer-aided engineering, and artificial intelligence, particularly in the design of interactive automatic control and communications systems.
- MIT, which will receive $2.2 million this year and as much as $20 million total to establish a **Center on Biotechnology Process Engineering.** Four areas will be stressed: genetics and molecular biology, bioreactor design and operation, product isolation and purification, and biochemical process systems engineering. The National Institutes of Health will cofund the center, with an initial grant of $100,000.
- Purdue University (West Lafayette, Ind.), which will establish a **Center for Intelligent Manufacturing Systems**. It will receive initial funding of $1.6 million and up to $17 million total. The center will focus on automation for batch manufacturing that will enable one factory to produce a wide variety of products. A central aim will be to develop a manufacturing system, capable of "semi-autonomous reasoning," to reduce cost, time, and errors.

It's likely that these centers will soon be joined by others. The Reagan administration's budget for fiscal 1986 includes $25 million for Engineering Research Centers, about half for second-year funding of the existing centers and the remainder for establishing another five or six. A new group of centers is expected to be chosen annually for at least three or four more years.

centers' directors tend to agree on the necessary ingredients for success. There has to be a good technical marriage, says North Carolina State's Chipsas. "We only want companies that are doing research on their own," he says, "because we work best as a catalyst." There also has to be a strong technical interaction for exchange of information. "It's important that the sponsor roll up his sleeves and get involved," says MIT's Cutowski. "A potential sponsor has to make a commitment that at least one engineer will be an active liaison to us." Without that commitment, the sponsor derives little benefit from the center and soon loses interest in providing funds.

The lack of this kind of technical exchange, in fact, was a prime reason for the most glaring failure of the NSF program. In the early 1970s, NSF established a furniture research center that, coincidentally, was also at North Carolina State. The center's purpose was to help the furniture industry develop new manufacturing methods. But the industry did very little research on its own, says Gray, so companies had no way of providing the R&D refinements for implementing any of the center's new developments. The companies thus lost interest, and the center died a premature death.

The most important requirement of all, says Ohio State's Grace, is that the centers show results. "Most industries," he says, "have to be able to show a return on their investment." At the same time, most research projects have to be relatively broad in scope; they cannot be tailored to one company's needs. "Companies simply do not want to see their proprietary research done in front of competitors," says Gray. Instead, says Norman Vogel, IBM's liaison at North Carolina State, "what the centers produce tends to augment what we are doing."

Nevertheless, the centers do perform some proprietary research in response to what Chipsas calls "enhancement," or supplementary, grants. He cites as an example a three-dimensional vision system developed for Westinghouse.

Convergence in research. The experience gained by these centers should be instructive to the ERCs, but the differences between the two programs are significant enough that the new research centers will have to chart some unfamiliar territory. To understand those differences, says NSF's Bloch, one must appreciate the distinctions among science, engineering, and innovation. "Science is the process of investigating phenomena," he says, "engineering is the process of investigating how to solve problems," and technological innovation "is the process that leads to more effective production and delivery of new or significantly modified goods or services."

Scientific research is represented by universities and conventional research institutes; the industry/university joint centers are slanted toward technological innovation; and the new ERCs represent the middle ground of engineering research.

Although these three areas are complementary, Bloch points out, there is no fixed "straight-line conceptual model" that characterizes their relationship. Too many research scientists, he says, "believe that discoveries flowing from their work drive engineering and

JON GOELL

Axiomatics' director of marketing Richard von Turkovich (left) and director of operations Frank Waldman pose with the monitor and flow-through sensor of the company's S-100 Moisture Sensor System for plastic resins. Axiomatics is a direct result of engineering research at MIT's Polymer Processing Center.

> *Most critical of all to the research centers will be industrial participation.*

technology. This is not only far too simple to describe the complex interactions. It is simply incorrect." There have been many cases, he notes, in which "useful invention went forward without the benefit of scientific work and in fact led to the development of principles or theory—indeed, sometimes to whole new areas of science." Volta's invention of the battery, for example, preceded by some 40 years Faraday's explanation of how batteries work, and the technology of photography was worked out by artists and craftsmen decades before physicists and chemists understood the principles on which it was based.

Similarly, the ERC directors would like the new centers to stay a jump ahead of scientific understanding. In many cases, in fact, progress will have to occur in this fashion if it is to occur at all. For example, "robotics systems research simply cannot be done in the conventional manner," says Susan Hackwood, codirector of the newly established ERC—the Center for Robotics Systems in Microelectronics—at the University of California at Santa Barbara. "We will have to go from the specific to the general, doing applications first and gaining fundamental knowledge later."

The mission of the Santa Barbara center is to apply robotics and automated process control to advanced semiconductor devices—improving fabrication, increasing yield, and reducing cost. One project already under way, for example, is the development of techniques for manufacturing long-wavelength semiconductor lasers for fiber optic communication. Such components are now very expensive—$2000 to $4000 apiece, versus about $50 for the semiconductor lasers now used in consumer products such as compact disc players—because gallium arsenide, from which they are made, is fragile and because the production yield is low. The center is designing robots capable of inspecting, testing, and handling these delicate devices.

The implementation of such projects requires the participation of technologists from several disciplines. Research at Santa Barbara will be carried out by a team of 16 professors from four departments: electrical and computer engineering, mechanical engineering, chemical engineering, and computer science. This type of cross-disciplinary interaction is expected to be basic to all the new centers. "I believe that when we look back on the centers in several years," says Bloch, "we will find that one of their main contributions has been to increase the flow of ideas and

people back and forth across disciplines. Areas of research are already beginning to converge, and the centers are designed to allow more integration and interaction."

This convergence is occurring not only among engineering disciplines, as at Santa Barbara, but also among science disciplines and between science and engineering. MIT's Center on Biotechnology Process Engineering, for example, will encompass several fields of biology, as well as chemistry, chemical engineering, and physics. Materials research at the University of Delaware's Center for Composites Manufacturing Science and Engineering requires solid-state physics, metallurgy, ceramics, and polymer chemistry, among other fields.

Delivering on their promise. This emphasis on cross-disciplinary effort, however, could creates a serious problem for the centers. "Most universities are now structured around discipline-oriented departments, and a faculty member's stature and rewards are determined by his peers within the discipline," says Larry W. Sumney, president of the Semiconductor Research Corporation (SRC), an industrial consortium that funds university-based research. By contrast, success in a cross-disciplinary collaboration requires the subordination of individual goals to those of the team. Thus without some adjustments in academic policy, says Sumney, interdisciplinary centers will be "predestined to a limited existence." Nam P. Suh, NSF's assistant director for engineering, not only agrees that "a strong institutional commitment to the center concept" will be required to overcome this problem but further suggests that "a change in the university's philosophy and approach to engineering research and education" may be required.

Although the Engineering Research Centers may initially cause some conflicts for faculty, they are expected to be of great benefit to students. Engineering schools have developed a major deficiency, says Jerrier Haddad, a former vice-president of IBM who is now chairman of the National Research Council's Commission on Engineering Education and Utilization. "In an effort to hold the undergraduate engineering program to a nominal four years," he says, "hands-on shop-practice courses have all but been eliminated." The undergraduate student who is not in a cooperative program thus receives virtually no exposure to engineering in an industrial setting, and even graduate students suffer from comparable limitations.

The new centers are expected to change this, at least in part. Research at the Santa Barbara center, for instance, will involve 20 engineering undergraduates and up to 50 of the university's engineering graduate students in environments very similar to what they will encounter upon graduation. As many as 400 students will also be enrolled in courses with laboratories like those found in industry; one industry-oriented course, in "reverse engineering," will be the first such offering at a U.S. university. In the same spirit, the Delaware composite center will eventually involve 50 graduate students and 30 undergraduates each year, and Purdue's Center for Intelligent Manufacturing Systems will have 120 and 80.

CHUCK PLACE

Gerardo Beni and Susan Hackwood are codirectors of the Center for Robotics Systems in Microelectronics at the University of California at Santa Barbara, one of the six engineering research centers established last April by NSF.

The proposed similarities between the university and industry environments will not only streamline technology transfer, says SRC's Sumney, but greatly improve the employability of graduates as well—a prospect not lost on today's students. "We're being inundated," says Hackwood at Santa Barbara.

Most critical of all to the ERCs, of course, will be industrial participation—not only in suggesting research directions and hiring graduates but also in providing financial support and applying the results.

Santa Barbara plans to have two types of industrial participants: sponsors in the Industrial Affiliates Program will pay a modest yearly fee, entitling them to send one company researcher to the school each year as a visiting scientist and to have access to experimental results before they are published. Sponsors in the Robotics Systems Program will fund specific projects, be entitled to assign several company investigators to the center, and have first access to the fruits of its research. Bell Communications Research, for example, is the primary sponsor of the work on long-wavelength semiconductor lasers at Santa Barbara, and plans to adopt the system upon its completion.

Response from industry has so far been excellent, says Hackwood. "We've already signed up half a dozen sponsors without even trying." Other center directors report similar results.

Participants in the ERC program draw encouragement from the success of NSF's Industry/University Cooperative Research Centers program. It demonstrated that industry and university investigators could work together effectively on specific projects and that university researchers could address the needs of industry. But because the old program had a much narrower focus, ERC participants are tempering their optimism with the expectation that the road ahead will be rocky. As George A. Keyworth II, director of the White House's Office of Science and Technology Policy, told the center directors when the awards were announced: "The good news is that you've survived what may have been the toughest grant competition in NSF history; the bad news is that now you have to do all the things you promised in the proposals." □

Thomas H. Maugh II is a freelance science writer based in Washington, D.C.

For further information see **RESOURCES** *on page 70.*

BOOSTING BUSINESS INTO SPACE

Support firms are helping manufacturers get their research off the ground

High launch costs generally inhibit space commercialization experiments by private companies. To ease this problem, NASA has for some time offered a Getaway Special (GAS) program for the Space Shuttle. Under this program, NASA will launch customer payloads at the bargain-basement rate of $50 per pound, a far cry from the regular shuttle cargo rates of more than $1300 per pound. The only provisions are that the payload be small (weighing no more than 200 pounds and occupying no more than 5 cubic feet of space) and that it meet NASA safety standards.

Unfamiliarity with NASA procedures and ignorance about the space environment have discouraged many firms from taking advantage of the GAS program. But three new companies—Instrumentation Technology Associates (ITA—Exton, Pa.), Getaway Special Services (Bellevue, Wash.), and Quartic Systems (Salt Lake City)—are ready to jump into the breach with a broad range of services and hardware for the organization interested in flying a small experimental payload.

ITA's basic product is a cylindrical aluminum rack containing shelves for holding customer equipment. ITA offers two such racks: a two-bay unit designed to fit into a small GAS canister supplied by NASA and a three-bay unit for a larger NASA canister. (The small GAS canister, with a volume of 2.5 cubic feet, is intended for payloads weighing 60–100 pounds; the large canister, at 5 cubic feet, can accommodate 200-pound payloads.) Three standard GAS environments are available: vacuum, air, or nitrogen.

by Bridget Mintz Register

Besides the equipment rack, ITA offers such basic experiment-support equipment as batteries, a data recorder, a programmer/sequencer, an accelerometer, and pressure and temperature sensors. Options beyond the baseline avionics include such equipment as cameras, video recorders, additional environmental controls, and experimental activators and indicators. An ITA customer may choose either light, compact aerospace equipment or heavier and larger but less expensive commercial-grade hardware.

"We're set up to service any kind of customer—from the aerospace company that doesn't want to put a package together, to the first-time user," says John Cassanto, ITA president. For the first-time user in particular, he says, integration services and knowledge of NASA are fully as valuable as the hardware. The novice customer comes to ITA with a basic idea for an experiment. ITA then designs and assembles the experimental apparatus, mates it to the GAS module, transports the payload to NASA, loads it onto the shuttle, and completes all the required paperwork and NASA safety tests. After the shuttle returns to earth, ITA returns the payload and the recorded data to the customer.

ITA president John Cassanto shows equipment racks developed by the company to support Getaway Special payloads.

Fees for ITA's payload integration service start at about $55,000, says Cassanto. This includes the lease of a payload module and basic avionics for the duration of the customer's experiment, as well as launch costs.

One of ITA's customers is the Bioprocessing Pharmaceutical and Research Center of the University City Science Center in Philadelphia. The experiment, under the direction of Paul Todd, is an investigation of protein crystal growth in space.

Sharing the same GAS canister is an experiment entitled "Production of a Semi-Permeable Membrane in Space," designed by Ivan Vera, a Venezuelan graduate student at the University of Pennsylvania. The project is funded by the National Electric Company of Venezuela and, according to Cassanto, may well be Latin America's first commercial space experiment.

For these experiments (both expected to fly in March 1986), ITA is providing the support structure, avionics, engineering design, and payload integration. The company is also integrating materials-processing experiments for two corporate customers, one based on the West Coast, the other in Philadelphia. (Both customers have requested anonymity.)

Like ITA, Getaway Special Services supplies modules for both sizes of GAS canister. They are made of a light foam-core composite that insulates experiments from the temperature extremes found in space, according to David Yoel, the company's president. The modules contain stackable trays that can be installed as the customer desires. The company also offers a broad range of supporting electronics gear.

Prices for the payload support modules depend on the type of customer. For schools, the company charges $9000 for the 2.5-cubic-foot module and $12,000 for the 5-cubic-foot structure. Rates for corporate customers start at $15,000. Fees for designing, building and integrating a small, passive experiment, says Yoel, would range from $35,000 to $50,000, not including launch costs.

Getaway Special Services' first customer was Booker T. Washington High School in Houston, whose physics and biology experiment flew aboard the shuttle in August. The company provided the support structure for a 60-pound canister, a controller, a data recorder, and a power supply.

In contrast, Quartic Systems does not provide payload integration services. What it offers GAS experimenters is electronic components. In particular, it supplies a computer and data recording system that draws only 15 milliwatts of power, according to company president Jim Elwell. This low power consumption makes the system ideal for GAS experiments, which must supply their own power in the form of batteries. Quartic Systems can also provide standard or custom-designed computer boards and cards, as well as complete software. So far, three GAS payloads have incorporated customized Quartic Systems boards; for a fourth payload, the company designed and built all the computer hardware and software.

All three companies face potential competition from the German aerospace giant MBB-Erno. The company reportedly plans to lease hardware designed for German materials-processing experiments in space, including a support structure and subsystems. In addition, the company will arrange launch services, financing, and insurance coverage.

But ITA's Cassanto is not concerned by the number of companies poised to compete in this small market niche. "The commercialization of space is going to snowball," he says.

Cassanto's belief in the future of the market is based in part on NASA plans to institute a program called Hitchhiker. The program will encompass payload modules of two different capacities: 750 and 1200 pounds. Besides offering bigger payloads than GAS, the Hitchhiker program will also offer payload support services. For example, the modules can be plugged into the shuttle's power supply, enabling experiments to draw as much as 1300 watts of power, according to Ted Goldsmith, Hitchhiker project manager at NASA's Goddard Space Flight Center in Greenbelt, Md.

The canister at top houses apparatus for a physics experiment destined for launch aboard the shuttle. The apparatus is supported by a lightweight foam-core composite structure (bottom) developed by Getaway Special Services.

The Hitchhiker modules will also contain an interface to the shuttle's data communications system. This will enable the shuttle crew to control experiments. In addition, customers on the ground will be able to send control commands directly to Hitchhiker payloads through a 1200-baud asynchronous transmission uplink. Similarly, payloads will be able to send results to ground-based experimenters via a low-speed (1200-baud) or high-speed (1.4-million-bit-per-second) downlink.

Hitchhiker prices have not yet been established, according to Alan Ladwig, manager of the Hitchhiker program at NASA headquarters in Washington, D.C. They are expected to be considerably higher than those of the GAS program, though still lower than the shuttle's standard rates.

Nevertheless, Cassanto sees Hitchhiker opening up new commercial applications beyond the low-gravity experiments made possible by the GAS program. "Hitchhiker is really the place where materials processing in space will bloom," he predicts.

And his company is ready to take advantage of the expected bonanza. ITA has developed a scaled-up version of its GAS experiment structure that is compatible with the two NASA Hitchhiker configurations and will have full access to the shuttle's power, communications, and telemetry circuits. The company plans to fly its first Hitchhiker payload for the Bioprocessing Pharmaceutical and Research Center in Philadelphia during the first quarter of 1987. Like the center's GAS package, that experiment (under the direction of program manager Richard Morris) concerns crystal growth in microgravity.

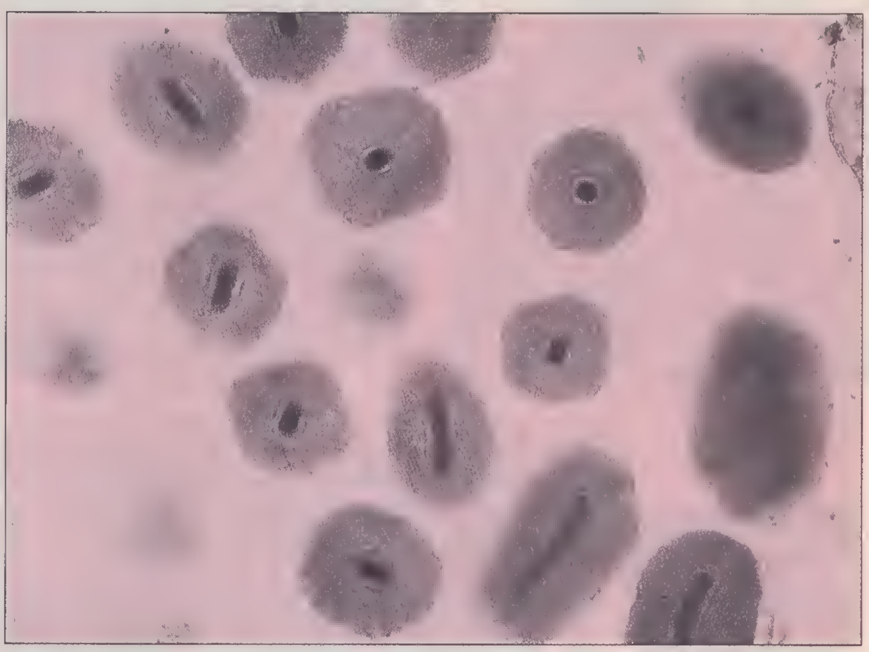
Unmanned space platforms being developed by NASA, the European Space Agency, and Fairchild should expand space manufacturing activity even further, says Cassanto. These platforms are designed to be carried into space by the shuttle, left in orbit, and later brought back to earth with their payloads. Because they will remain in space for extended periods—unlike the shuttle, which can remain in orbit for only a week—the platforms could be used for manufacturing semiconductors, pharmaceuticals, and other materials in sizable quantities. In addition, the advent of NASA's space station, currently scheduled for completion by 1992, will expand the market still further by allowing the use of manufacturing processes that require human monitoring.

Cassanto thus expects space platforms, both unmanned and manned, to increase demand for the kind of payload integration services that his company offers—hence his lack of concern about the already growing competition in the market. "There will be room for all the competitors," he says. □

Bridget Mintz Register is a Houston-based freelance writer who specializes in space-related topics.

PROTECTING CROPS WITH VIRUSES

New pesticides home in on insects without harming other species



Rod-shaped Baculovirus *particles often exist within a tough protein matrix (here enlarged 40,000×). The particles are released by protein-destroying enzymes found almost exclusively in insects.*

The term *magic bullet* is often used to describe a drug that kills only one type of cell (usually a cancer cell). But the idea has been extended to a novel class of insecticides: viruses that kill just one or a very few types of insect. Several private and government researchers in the U.S. are convinced that continued commercialization of these products will add a potent new weapon to the nation's $800-million-a-year arsenal of insecticides.

Still, even proponents concede that the young technology faces several obstacles: high costs, a short field life, and resistance by farmers who prefer to stay with tried and true chemical and bacterial products. Only one company, MicroGeneSys (New Haven, Conn.), is now selling viral insecticides. Others are said to be studying the market closely, however, as they weigh the obstacles against several clear advantages, including the viruses' high degree of selectivity and the fact that unlike potentially hazardous chemical insecticides, the virals are based on ubiquitous organisms that are harmless to nontargeted life forms.

All living things are believed to be subject to viral infection. And while some viruses infect many different species, others attack only a very limited number of targets, or hosts. Of the organisms known to infect insects, the most promising are members of the *Baculovirus* group—rod-shaped particles made up of a protein coat surrounding a core of DNA. The *Baculovirus* occurs in two forms. In one, called a polyhedral inclusion body (PIB), the particles are embedded in a hard protective matrix of a second protein, called polyhedrin; in the other, called non-occluded virions (NOVs), the virus occurs as free particles.

by Kenneth E. Sherman

Most of the research on these viruses has centered on the types that infect the larval (caterpillar) forms of agricultural and forest pests. One insect group, classified as *Lepidoptera*, includes many of the plant-eating caterpillars that cost farmers millions of dollars a year. *Lepidoptera* such as gypsy moths, cabbage loopers, cotton bollworms, and fall armyworms have voracious appetites for specific plant types when they are in the larval stages.

The viral infection process starts when a caterpillar ingests the microscopic PIBs that are deposited on the leaf surfaces. Inside the insect, the PIBs are broken down by enzymes called proteases, which work effectively in the alkaline environment of the gut. These enzymes are relatively rare in the animal kingdom; higher species (including mammals) cannot break down the strong PIB protein coating, so ingested PIBs are simply excreted intact.

In the insect, however, viral particles are liberated and adsorbed onto cell membranes. The virus passes into the cell and quickly heads toward the cell nucleus. Along the way, the internal protein coats are lost, and the viral DNA proceeds to take over the cell for self-replication. The cell becomes filled with both PIBs and free NOVs (a dichotomy that appears to be important to the virus's life cycle). The NOVs spread and multiply quickly throughout the insect. Within a few days, the cellular damage is so extensive that the insect dies, releasing the PIBs to the environment. The process then repeats as some of the particles find their way onto nearby leaves, to be ingested by another insect.

The widespread use of *Baculovirus* would not likely pose a threat to other species. In fact, we are already exposed to the organisms on a rather grand scale. One recent study of more than 100 untreated Maryland fields found the cabbage looper *Baculovirus* in almost 70% of them; another Maryland study reports that cabbage leaves in local supermarkets carried over a million PIBs per square centimeter.

To produce commercial viral pesticides, laboratory stocks of the host in-

sect are first infected with the *Baculovirus*. As the virus reproduces itself, the number of PIBs per insect is maximized by carefully controlling the insects' diet and other conditions. When virtually all of the "production batch" of insects are infected, the larvae are harvested and the PIBs removed by straining, washing, and centrifuging the viral products.

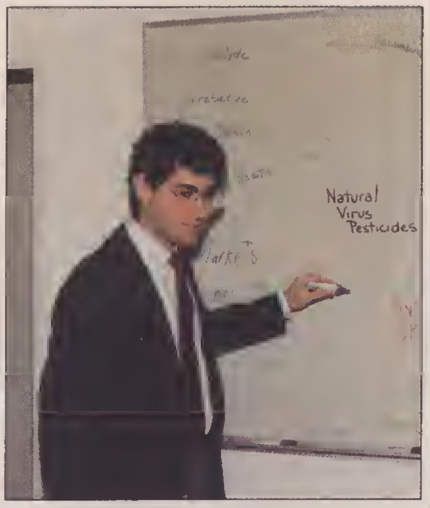
Baculovirus can also be grown by tissue culture methods, in which sheets of insect cells are placed in flasks containing a nutrient growth medium. The cells are then harvested and broken up with sound waves, and the virus particles are purified. This method is simpler and easier to control than production in live insects. The yield is lower, however, and the cost still discouragingly high.

Finally, the purified PIBs are mixed with an inert carrier. The mixture is then applied with the same equipment that is used for chemical pesticides, at the rate of a few grams per acre. Although the PIBs are extremely resistant to breakdown by bacteria and most other environmental factors, they are susceptible to ultraviolet radiation; mixtures must therefore contain a sunscreen to prolong the particles' effective lifetimes.

In terms of market acceptance, viral pesticides are off to a shaky start. The first commercial viral pesticide was approved in the early 1970s for U.S. production by Zoecon (Palo Alto, Cal.), a subsidiary of the Swiss firm Sandoz. The product, called Elcar, was aimed at controlling the cotton bollworm. Production was halted about two years ago, says product manager Lon Seymour, because of high production costs and reluctant consumers. As a result, he says, Zoecon is concentrating on more familiar (and more economical) bacterial pesticides.

During the late 1970s, Sandoz also produced an insecticide based on the type of granulosis virus that infects the codling moth (*Cydia pomonella*). Like Elcar, the product was discontinued because of its high price. The insecticide, which protects apple and pear crops, is now being developed by MicroGeneSys (pronounced "micro-genesis") under the trade name Decyde. The company is confident that it can make the product for less.

MicroGeneSys is also producing a viral insecticide called Preserve, which protects Christmas trees and ornamentals against the European sawfly. According to company president Franklin Volvovitz, the product is equivalent to an earlier insecticide called Neochek S, which was based on research by the USDA's Forest Service and which is reportedly being produced by the British firm Tate and Lyle. For now, says Volvovitz, "we are the only U.S. company committed exclusively to viral insecticides."



Compared with competing products, viral insecticides are more selective and less likely to cause resistance among pests, says MicroGeneSys' Volvovitz. For now, the company is alone in bringing the technology to U.S. markets.

Three other viral insecticides—against the gypsy moth, the tussock moth, and the sawfly—have been tested by the Environmental Protection Agency, and the Forest Service is now encouraging companies to look into joint licensure of these products to make them commercially available. "It would be beneficial for industry to pick up on the basic technology that we have developed," says Dennis Hamel, a Forest Service entomologist in Rosslyn, Va. The insecticide technology is in the public domain, he notes, and thus production and marketing information is available to anyone.

Several chemical and biological companies have inquired about joint licensure, he says, but the main reaction so far has been "thanks but no thanks." One reason is that while government laboratories are rich sources of basic research, such data usually fall short of what is needed for more direct implementation of the technology. "The government may provide some helpful background," says John Davies, president of Ecogen (Lawrenceville, N.J.), "but it's often of limited commercial use. We generally prefer to bring our own resources to bear on these projects." (Davies adds that Ecogen has not

GRANT HEILMAN

U.S. farmers spend $800 million a year to protect apple orchards (above) and other crops from insects. Virals could take a healthy share of that market if production costs are reduced and customers are convinced of their safety.

permanently ruled itself out of viral products.)

Another reason for companies' sluggish response to the Forest Service could be the continuing interest in bacterial, rather than viral, pesticides. "The whole area is still very young," says Davies. "And for now, much more is known about bacteria than about viruses." One of the most successful insecticides of recent years, in fact, was the one based on the bacterium *Bacillus thurigensis*, which was widely employed during the 1981 gypsy moth onslaught in the Northeast.

An even bigger advantage of bacterial products, says Davies, is that they can be produced *in vitro*—that is, they do not require living "virus factories," but can be manufactured economically in industrial fermenters. "That makes their price competitive with standard pest-control chemicals," says Davies.

But Volvovitz at MicroGeneSys remains sold on viruses, claiming that bacteria are almost completely ineffective against some insects, are less selective than viruses, and are more likely to cause resistance among targeted insects. The company is also developing viruses as agents for transferring foreign genes into bacteria in the production of recombinant DNA chemicals and pharmaceuticals.

Despite their potential, viral insecticides will not soon spell the end for their chemical counterparts. The high cost of producing and obtaining EPA approval for virals will probably keep large firms out of the market until it reaches $50 million a year or so, according to Technical Insights (Fort Lee, N.J.), publisher of a genetic engineering newsletter. However, Volvovitz says it's "very easy" for a firm like MicroGeneSys, with its lower overhead, "to enter a much smaller marketplace—say, $5 million a year or so."

The most likely outcome will be the growth of "integrated pest management" (IPM). As its name implies, an IPM program draws on different types of insecticides—viruses, bacteria, and chemicals—depending on the nature of the insect problem. Chemicals will continue to be the treatment of choice when the insect is known to resist bacterial products, for example, while virals and bacterials will get the nod in cases of unusual environmental sensitivity. □

Kenneth E. Sherman is a freelance writer based in the Washington, D.C., area. He holds a PhD in microbiology.

MODEM MADNESS

Faster machines have brought a bewildering array of competing protocols

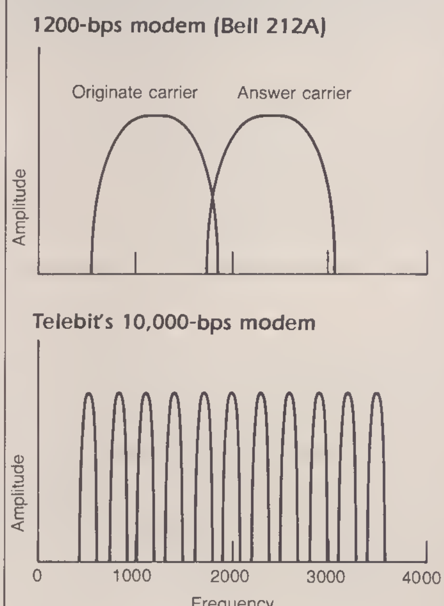
Telecommunications with microcomputers promises a link to the world, a way to get the latest stock market reports and political gossip. Someday such links will be fast and efficient, but for now they are more often merely frustrating; telecommunications takes on too many incompatible forms. And unfortunately, the near-term prospects are that things will get worse before they get better. The latest technologies—such as the new crop of 2400-bit-per-second (bps) modems—magnify both the promise and the problems.

Nevertheless, the technology is already available for much better communications, and the most successful ideas should ultimately make order out of the present chaos. Today's confusion arises from the way the standards were set. For example, the Bell protocols were established at a time when AT&T dominated American telecommunications and the Bell System built and leased model 103 (300-bps) and 212A (1200-bps) modems. Companies trying to make compatible units could and did get such Bell modems for testing their own products. Yet V.22 bis and other international standards, set by the International Telegraph and Telephone Consultative Committee (known by its French acronym, CCITT), consist only of recommendations on paper, not actual modems. As a result, companies interpret the recommendations in their own way.

Today, the area of greatest confusion is higher-level protocols. A case in point is error detection and correction—the need for which is growing as modems become faster (higher speed tends to increase problems with signal quality). Most error correction techniques break the transmitted information into blocks. From the specific data in a block, the sending computer calculates a number and adds it to the end of the block. The receiving computer calculates the number independently; if the results don't match, the receiver calls for the block to be re-sent.

by Cary Lu

So far, so good. But the manner in which the error checking is accomplished is crucial to overall speed. The most popular error correction scheme for microcomputers, Ward Christianson's Xmodem protocol, employs the data channel in only one direction at a time. After the sender transmits a block, it waits for an acknowledgement before sending the next block. Hence, on a satellite hookup at 2400 bps, the delays are considerable; 80% of the time is spent waiting for acknowledgements. And Xmodem uses a fixed block size suitable for transferring relatively large chunks of data but unsuitable for interactive sessions, where it's likely that only a few characters will be sent at a time.



Top: Frequency spectrum for 1200-bps modem shows two separate carriers handling two simultaneous signals. Bottom: Telebit's 10,000-bps modem uses up to 512 carriers at a time. Each carrier, separated by 7.8 Hz, transmits 7.3 signal events per second (baud). Each baud codes up to six bits.

MARK E. ALSOP

Two new error-correcting protocols seeking acceptance are Tymnet's X.PC (an asynchronous form of X.25, a network protocol) and the Microcom Networking Protocol (MNP). Both have more robust error correction than Xmodem, and both have variable block size for interactive sessions. What's more, they use a "sliding window" approach to error correction; that is, the sender transmits blocks continuously, and the receiver checks for errors, if necessary calling for a block to be resent even as other blocks arrive.

X.PC handles only raw information transfer—individual characters or the contents of a file. Designed for interactive sessions using the Tymnet data communications network, it permits simultaneous multiple sessions for a suitably equipped dial-up database. You can get a stock market ticker tape at the same time as you are retrieving other information.

MNP does not permit multiple sessions but is otherwise more comprehensive, able to transfer not only a file but also the file name and related information. An MNP-equipped system will automatically check whether the receiving system can understand MNP and whether it has enough disk space to store the file. Although MNP works best when supported with dedicated hardware, it can be implemented with software alone. MNP's higher-level protocols are not completely specified, opening the way both to improvements and to incompatibilities.

Tymnet and Microcom have been busy lining up supporters for their protocols. Microsoft's new Access telecommunications program includes X.PC, and Hayes has announced its forthcoming support. Tymnet's main interest is getting people to use X.PC for interactive sessions on its dial-up services. To individual users, multiple sessions will have a limited appeal, but to information providers, the opportunity to bill for simultaneous sessions is certainly attractive.

As for MNP, several modem manufacturers are supporting the protocol, but many potential licensees have had reservations about Microcom's mar-

keting strategy. Although a license costs only $2500, Microcom had been demanding the right to use the licensee's name in advertising. Hayes, the leading microcomputer modem maker, has refrained from supporting MNP. (Tymnet placed X.PC in the public domain.)

But the choice of error correction protocol need not be an either/or proposition. Microstuf's new Crosstalk Mark Four, for example, supports both X.PC and MNP.

Among other contenders, the Kermit error correction protocol was developed at Columbia University for tying microcomputers to mainframes. In an effort to achieve maximum compatibility, Kermit uses only 7-bit characters during communications, so it is inherently inefficient; it probably will not spread much beyond academic circles. Nevertheless, Crosstalk Mark Four does Kermit as well.

For the new mobile phones using cellular radio, Spectrum Cellular has introduced a special modem and software protocol. Although a conventional error correction scheme would work in principle, standard modems would often disconnect because of the signal loss during hand-offs from cell to cell, and the frequent dropouts and pulse noises in a radio link would cut efficiency severely. Spectrum Cellular combines a sliding window correction system for long disruptions and a multiple parity bit correction for short disruptions. Over a perfect link, the additional error correction overhead takes up about a third of the transmission time, but on a typical radio link (with a signal-to-noise ratio of about 15 dB, versus 27 dB for a local land line), Spectrum Cellular keeps going when other systems fail. Its initial $695 modems work at 300 bps only, but 1200-bps units are planned.

All telecommunications protocols require that both sender and receiver use the same protocol—so in order to succeed, a protocol must be widely adopted. This need often makes the introduction of newer and better ideas difficult. For example, the Popcom modem from Prentice can switch quickly and easily between voice and data, but only when both sending and receiving modems are Popcom units. Similarly, any error correction protocol works only if both sides are employing it. The Spectrum Cellular protocol requires matching units at both ends, but the company is trying to convince the cellular radio operations to use it at their control centers; a protocol converter would forward a more conventional data stream to the destination modem.

As communications traffic gets heavier, all the common speeds, including 2400 bps, seem slow, and error correction schemes make things slower still. Fortunately, several techniques can increase the effective speed of present modems. The "squeeze" and "unsqueeze" programs available from user groups employ the Huffman coding algorithm to cut text files down to about half the length by assigning frequently used letters codes that are shorter than full bytes. Such compression techniques may be incorporated into communications programs in the near future.

For even tighter compression, the Datran Modem Accelerator uses special processor hardware to collapse entire words into short tokens, cutting files to a third their original length. A word look-up table stored in read-only memory does the trick, and the same hardware on the receiving end expands the file back into original form. The $795 Datran Accelerator is most useful for sending large text files, something that usually need not be done interactively. While a pure software equivalent could operate at much lower cost, you would have to preprocess and postprocess the file separately from the communications step.

Most compression techniques work only on text files, but new methods can compress many file types, including pictures. Although compression is useful in general, combined with faster modems it's even better. Beyond 2400 bps, modems suffer from high cost and—at present—limited applicability. The common 4800- and 9600-bps protocols are used mainly on leased telephone lines. The new V.32 (4800- and 9600-bps) protocols permit full duplex operation over dial-up lines, but the modems are just beginning to ap-

The woes of faster modems

Ordinary telecommunications uses modems, hardware that converts digital signals into analog audio form for standard telephone lines. At the most common speeds—300 and 1200 bits per second (bps)—the modems used in North America are incompatible with those officially used in Europe and Japan (although as it turns out, many American modems are sold in Europe on the gray market). Following the appearance of a Rockwell integrated circuit chip set, the new 2400-bps modems are proliferating and, fortunately, employ the V.22 bis protocol worldwide. One discrepancy, though, is that the European answer tone (21 kilohertz) is different from the American one (22 kHz); while calls from North America to Europe generally work, the reverse isn't always true.

To achieve their speed, the new 2400-bps modems are adaptive: During the initial handshake, they adjust their sending and receiving equalization to the condition of the telephone line. The V.22 bis protocol uses more bandwidth than the slower modems, so telephone line quality is a major consideration. Local calls rarely cause difficulty, but long-distance lines may not have sufficient quality for reliable links. According to Ken Krechmer of Action Consulting (Palo Alto, Cal.), the signal-to-noise safety margin for typical modems operating on pre-divestiture AT&T long-distance telephone lines was 16 dB at 300 bps (Bell 103 protocol), 10 dB at 1200 bps (Bell 212A), and only 3 dB at 2400 bps. As price competition among the long-distance services causes the quality of long-distance lines to drop, many phone lines simply won't support 2400-bps links.

To cope with noisy lines, V.22 bis calls for modems to fall back automatically to 1200 bps during the initial linkup. The fallback is supposed to be to V.22, but since this protocol is not used in North America, some American-made V.22 bis modems fall back to Bell 212A instead, and a few designs will not fall back at all. In either case, the link will be broken.

Companies

Digital Communications Associates, 1000 Alderman Dr., Alpharetta, GA 30201, (800) 241–4762
Microcom, 1400A Providence Hwy., Norwood, MA 02062, (617) 762–9310
Microsoft, 10700 Northup Way, Bellevue, WA 98004, (206) 828–8080
Microstuf, 1000 Holcomb Woods Pkwy., Suite 440, Roswell, GA 30076, (404) 998–7798
New York Amateur Computer Club (public domain software packages for IBM PC, \$7 each postpaid; Squeeze and Unsqueeze on disk 81, Kermit on disk 107), PO Box 106, Church St. Station, New York, NY 10008
Prentice, 266 Caspian Dr., PO Box 3544, Sunnyvale, CA 94088-3544, (408) 734–9810
Telebit, 10440 Bubb Rd., PO Box 4040, Cupertino, CA 95014, (408) 996–8000
Tymnet, 2710 Orchard Pkwy., San Jose, CA 95134, (408) 946–4900

pear. V.32 uses echo canceling, a technique whereby each modem listens to and cancels out the effects of its own signal, permitting two modems to use the same frequencies in the channel. V.26 ter also uses echo canceling at 2400 bps and could possibly displace V.22 bis, because it is more compatible with V.32.

A new modem technology offers a chance to leapfrog V.32. Telebit's 10,000-bps TrailBlazer modem (also sold as Fastlink by Digital Communications Associates) takes a radical approach to communications, using up to 512 audio carrier frequencies, each separated by 7.8 Hz, on a dial-up phone line. Each carrier is modulated at a rate of 7.3 Hz, and each modulation can code as many as six bits. During the initial setup, the receiving modem tells the sending modem which carriers it is receiving successfully, and the sender adjusts its transmission accordingly.

Error correction is integral to the process. Momentary errors are corrected with retransmission, but if the errors persist, the modems go through the setup cycle again, changing the carrier frequencies as required. Although on a high-quality line the modem actually operates at a maximum data rate of some 14,000 bps, error correction lowers the throughput to about 10,000 bps. With the Telebit protocol, speed fallback for noisy lines is done in increments of less than 100 bps, a more gentle progression than the 50% speed reductions applied by other protocols. On poor to fair lines, the throughput can drop to 7000 bps or lower. On the really bad lines, the Telebit protocol can still usually get some data through even when other protocols give up altogether.

From the standpoint of the communications channel, the Telebit protocol is half duplex; at any instant the transmission goes only one way. Functionally, the protocol can turn the line around fast enough that users perceive it as full duplex. As with any half duplex system, performance on satellite links suffers from delays in transmission time. But because Telebit uses a large packet size, the speed penalties aren't too severe—from about 20% for long files to about 65% for small packets (which normally occur only during interactive sessions, when throughput isn't critical).

For Telebit to render the CCITT V.32 and other "fast" modem protocols obsolete, it will need widespread adoption, so Telebit will probably have to pursue an aggressive licensing policy. For compatibility with present standards, the \$2000–\$2300 Telebit modems include the Bell 103 and 212A protocols.

Ultimately, modems will give way to direct digital phone service, which will obviate the need to convert signals into analog form. Dataphone digital service (DDS), running at 56 kilobits per second (kbps), is already available—although costs and usage restrict it to specific installations. The forthcoming Integrated Services Digital Network (ISDN) supports two 64-kbps channels of digitized voice or data. Unfortunately, the widespread adoption of such fast links awaits the massive installation of optical fiber trunk lines between telephone exchanges. □

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

SCANNERS PUT DESIGN ON LINE

Machines that digitize text and graphics are finding a niche in CAD/CAE

Computer technology is constantly presented as both the embodiment of the present and the way of the future. It's therefore easy to overlook the importance of forging strong electronic links to the "past"—all the information residing in typewritten documents, hand-drawn charts, and other materials created independently of computers. To fulfill their role as "information processors," computers must access this information and somehow merge it with data already stored in electronic form.

The need to electronically digest various forms of printed and drawn material is especially acute in engineering companies that are attempting to modernize through the use of computer-aided design (CAD) and computer-aided engineering (CAE) equipment. The benefits of CAD and CAE, while considerable, are attainable only on drawings that exist in the computerized database; today there may be as many as 100 million "active" designs that are not in CAD databases. What companies need is a "magic slot" into which they can place a page and have it transformed into digital form, according to Joel Orr, president of the consulting firm Orr Associates (Danbury, Conn.).

Fortunately, such a magic slot exists in the form of hard-copy scanners—devices that electronically "capture" data, either by recognizing printed letters and numbers or by breaking all the marks on a page into bits of data that can be stored and then reconstructed on a video screen or a printer. These products go by various names, including data capture and conversion devices, digital art and text capture

by John M. Garvey

Scanners such as this Skantek SK-1010 automatically convert engineering drawings into computer-based digital data that can be viewed and modified on computer-aided design systems.

systems, drawing digitizing systems, graphics input workstations, and automatic scanners and digitizers. Whatever the name, advances in the underlying semiconductor technology have improved the accuracy of these machines, reduced their prices, and increased data-entry productivity by as much as four or five times.

Scanners have been available for some time, but the earlier versions were of narrow use. For instance, scanners have been reading the specially shaped numbers on checks for many years. Inherent restrictions of product cost and required computer intelligence, however, limited the technology to such high-volume applications.

The present scanning market has many niches. Hand-held scanners costing as little as $500 recently became available for individual personal computer users. Scanners for office use, whose principal application is to "read" pages of text into word processors, can be purchased for a few thousand dollars. At the upper end of the market, sophisticated scanners can cost $1 million or more. These are primarily laser devices used in publishing to create very-high-resolution half-tone photographs and color separations.

Scanners that can digitize engineering drawings and associated characters fall somewhere between the two extremes. The current generation of these scanners can digitize varying typefaces (some even recognize hand lettering), as well as the complicated graphics found on large engineering documents. In the latter case, an American National Standards Institute (ANSI) standard developed to make the exchange of graphics information easier—the Initial Graphics Exchange Specification (IGES)—has facilitated the development of scanners for this market.

Engineering scanners typically combine the two fundamental scanning technologies: optical character recognition (OCR) and bit-image capturing. OCR uses various pattern recognition algorithms to identify typed or printed letters and numbers, matching the characters on a scanned page to those stored in its database. Once recognized, a character is converted to a 7-bit code (ASCII) for storage and further manipulation.

Bit-image capturing is used to digitize graphics or characters that the OCR software can't identify. This technique essentially breaks the document into thousands of individual points, or "pixels," and records whether or not a mark exists at each location. Most scanners work at a resolution of about 200–300 dots per inch and generate a stream of bits that can be reconstructed to form an image of the document. This bit stream, however, is more difficult to manipulate than the well-ordered ASCII character codes, and it takes up a lot more storage space. The higher the resolution, the more storage required. Using OCR instead of bit-image technology can result in a 20-to-1 saving in storage requirements.

All scanners essentially consist of a data capture subsystem and an image-processing subsystem. The data capture component consists of a document holder, a means of illuminating the document, and a light detector (or aperture). The document holder can be of the drum, flatbed, mirror, or roll-feed type. Illumination can be supplied by lasers, LEDs, incandescent lamps, or cathode-ray tubes (CRTs). The detection can be performed by acousto-optics, by an electron beam, or by optical fibers.

The image processor is a software-

intensive component that converts the analog optical signals received from the document to binary digital signals (ASCII codes or bit streams). These signals can be further modified to fit into a specific CAD system's data format. Work in such fields as advanced pattern recognition and artificial intelligence promises to significantly enhance the image-processing capabilities of such scanners.

In the CAD/CAE world, the conversion process for large engineering drawings is extremely complex. According to Orr, there are at least four major obstacles:

• *Raster-to-vector conversion.* The bit-image scanner "sees" a drawing as a series of pixels, or as a "raster" image. But CAD systems understand the less storage-intensive "vector" mode, in which a line is not viewed as a series of dots but as the coordinates of its end points.

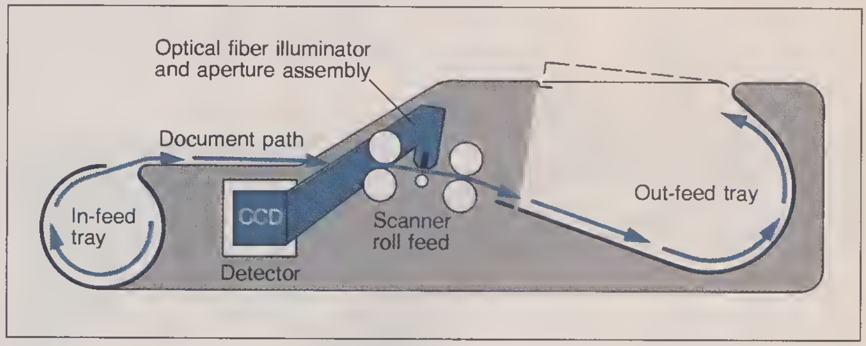
• *Symbol recognition.* A scanner must be able to recognize not only text but also certain geometric entities. A CAD system, for instance, recognizes a circle as a center point and a radius; for compatibility, the scanner ought to have the same "understanding."

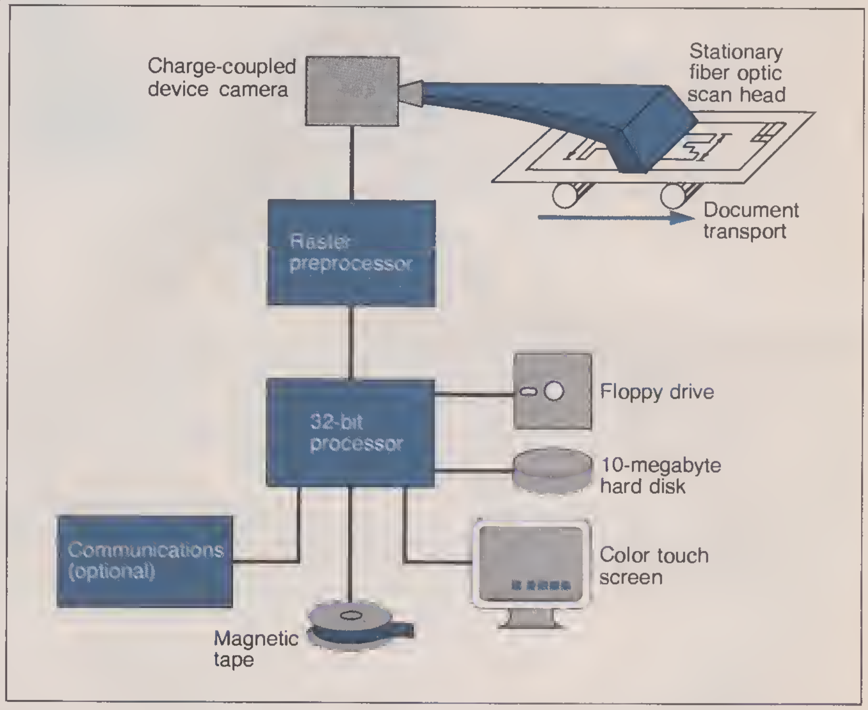
• *Association of text and geometry.* An engineering drawing has graphic elements with textual notations giving the dimensions of those graphics. A scanner must know that the two are related.

• *Dimensional ambiguity.* Beyond knowing that text and graphics must be associated, the scanner must be able to resolve (or at least recognize and highlight) ambiguity. For example, a line on a drawing might be two inches long, but the text says it should be two and a quarter inches. Which is correct?

The obstacles are so considerable that some observers question whether engineering-drawing scanners are worth the fuss. "I'm not convinced these scanners are needed," says Bertram Herzog, of Computer Graphics Consultants (Washington, D.C.). "The real issue is whether or not all of the drawings need conversion." But, he adds, "as cheaper devices with more functionality become available, the more irrelevant my caution becomes."

As with many electronic developments, the military is to a large extent the prime mover behind the current rush toward drawing conversion. In early 1984 the U.S. Navy commissioned Peterson Builders (Sturgeon Bay, Wis.) to construct the first in a series of new minesweepers known as MCMs ("mine countermeasure" ships). The twist was that for the first time the Navy required the entire set of drawings, which had been created by hand, to be delivered in digital form so that the design could then be transmitted to other builders.





Top: Rather than scanning a drawing on a flat-bed surface, the SK-1010 uses a roll-fed system. Bottom: Optical fibers illuminate the drawing; the reflected light is picked up by another row of fibers and transmitted to a charge-coupled device (CCD) detector/camera. The detector generates digital signals, which are converted by a preprocessor from raster to vector code that can be stored, transmitted, or displayed.

DAVE HANNUM

Peterson was therefore required to convert to digital form over 750 drawings, some of them ANSI "H" size (28 inches wide and up to 12 feet long). "We had a commitment to the Navy and three ways to fulfill it," explains Randy Graf, Peterson's CAD manager. "We could manually recreate all the drawings on our CAD system; we could convert each drawing into digital form by using a mouse and a digitizing tablet; or we could use automatic digitizing. We felt the automatic technology was ready, and we wanted to be the first to apply it." The choice was a good one, he says, even though the computer files created sometimes required up to 20 hours of editing once on the CAD terminal. "Using this technology, we have averaged a two- or three-to-one productivity gain over what we would have had with the other two options. We probably couldn't have done it any other way."

Skantek (Warren, N.J.), the supplier

of the scanner used by Peterson, operates on the premise that there is currently no such thing as perfect scanning. It has produced a scanner that, priced from $125,000 to $165,000, is one of the least expensive in the engineering marketplace. While the company admits that its self-contained SK-1010 product does not create perfect CAD data files, it maintains that the device is cost-effective. Once the drawing data are captured, they can be edited on the CAD system as necessary.

"Scanned files will *always* need editing at the CAD terminal," says Skantek president and CEO Roger Paradis. In digitizing graphics and text, scanners may make errors that must then be corrected manually. Also, operators might choose to rekey bit-imaged text to get it into the more managable ASCII format. To reduce the editing time required, Skantek recently introduced an OCR software package that reportedly recognizes hand-lettered characters as well as machine-produced letters, numbers, and special engineering symbols done in such block typefaces as Leroy and Varityper.

Other military projects using Skantek equipment are DSREDS (Digital Storage and Retrieval of Engineering Documentation System) at the U.S. Army Missile Command in Huntsville, Ala., and EDCARS (Engineering Data Computer Assisted Retrieval System) at McClelland Air Force Base in Sacramento, Cal. These projects involve the digitization of more than 4 million engineering drawings.

The projects' specific purpose is to create a central database to serve as a drawing management system containing all the varied information pertinent to bid packages. Such an undertaking only recently became feasible, thanks to the coupling of scanning/digitizing technology with high-capacity optical disc storage.

At the upper end of the engineering scanner marketplace sits SysScan, a joint venture of Germany's Messerschmitt-Bolkow-Blohm and Norway's Kongsberg Vaapenfabrik. The company produces a family of automatic digitizing scanners; its DATOS system achieves a resolution of 500 dots per inch, which is almost twice that of most other systems. The scanner can therefore also address markets beyond engineering, such as those involved with the creation of line art and half-tone photography.

SysScan's system comprises a dedicated mainframe or superminicomputer, a high-resolution flatbed scanner with a moving head, raster-to-vector workstations, a conversion module link to CAD devices, and various peripheral output devices such as typesetters and plotters. At a cost of approximately $450,000, this package can facilitate the production and updating of engineering documentation. It also allows information to be transmitted digitally via ground or satellite links to remote sites for storage or manipulation.

Somewhere between the Skantek and the SysScan approach is that of Metagraphics (Woburn, Mass.). Its $300,000 system can transform paper drawings into "intelligent" data files by means of a two-station approach. The "scan" station consists of a flatbed document holder and stationary camera with an attached graphics display terminal and a central processor. It is at the second, or "edit," station that artificial intelligence comes into play: Using a process Metagraphics calls rectification, the system is able to discern a wide range of contradictions and/or omissions on a drawing. (SysScan offers a similar feature it calls dimensioning.) If the dimension of the same element is different in one view than in another, for example, the operator is notified. Metagraphics, which expects its system to generate CAD designs that can be sent directly to the factory floor for tooling on numerically controlled machines, plans to begin shipments of its product late this summer.

Many other firms are active in this market, including start-up Optigraphics (San Diego), electronics giant Tektronix (Beaverton, Ore.), AutoCAD (Sausalito, Cal.), and Israel-based Scitex. Despite the technical challenges they face in the engineering marketplace, says consultant Orr, "most scanner manufacturers will probably be able to find niches for particular applications." As improving technology increases the accuracy and efficiency of these devices, a growing number of manufacturers will likely use them to bring their existing engineering drawings into the computer age. □

John M. Garvey is a freelance writer and audiovisual specialist living in Landing, N.J.

PERSPECTIVES

Technology "brokers" meet limited success

The business of transferring technology out of universities—licensing academia's flood of inventions for commercial application—is not a business for the quick-buck artist or the faint of heart. Because of long product-development times and the difficulties of identifying the few commercially viable ideas in the vast well of university research, companies seeking to profit from the brokering process must often tolerate long strings of failures and extended periods of little return.

For example, University Patents, Inc. (UPI—Westport, Conn.), which has been in the technology transfer business for 13 years, lost $1.1 million in 1984. UPI chairman L. W. Miles attributes the loss—the company's first—to the launch of new subsidiaries, and believes that profits "will come with products not yet on the market."

UPI's eight client universities manage a combined annual research budget of about $600 million, giving the company about 200 inventions a year to consider. Each is evaluated for its technical feasibility, its commercial potential, and—equally crucial—its patentability. This laborious and expensive review requires a professional staff of 14, including financial and business analysts, patent attorneys, and PhD scientists, to select the 40 or so inventions the firm will attempt to take to market each year. Overall, UPI has commercialized 130 university-created technologies, including the Plato line of teaching software, developed at the U. of Illinois; a machine for making gene segments, from the U. of Colorado; and the touch-screen that Hewlett-Packard uses in its personal computers, also from Illinois.

Typically, UPI keeps 40% of the university's royalty from any technology the firm licenses. UPI funds some university research directly; in those cases, the company takes a larger share—as much as 70%—from commercial discoveries. Colorado's gene machine, for example, came out of research partly sponsored by UPI.

A technology transfer company's success is based on the volume of ideas it can evaluate. "About ten out of every hundred inventions have good patent prospects," says W. Stevenson Bacon, spokesperson for the Research Corp. (Tucson), which has been active in tech transfer for 50 years. "Of those, we might be able to license three. Perhaps one or two will pay the cost of their own licensing. About one in a thousand will be a really big winner."

Some universities, hoping to keep from sharing any potential royalty income, attempt to license faculty inventions on their own. "Many more schools are working on their own behalf now," says Bacon. "They've been sensitized to the value of patent rights, and they think they're going to make big money."

That rarely happens, though, he says, because institutions often assign the complex work of commercializing faculty inventions to a part-time administrator lacking a technical or legal background. The school frequently neglects to file for patents abroad, a failure that Bacon says is "guaranteed to kill industry's interest in an invention." In another common pitfall, a school tries to find a licensee first, and have that person or organization apply for the patent. This move can not only cost a school a majority share of the royalty income but also embroil it in legal controversies. "When universities try to do what we do, they often underdo it," says UPI's Miles. "So they wind up with 100% of nothing instead of 60% of something."

Aladdin Industries (Nashville) takes a different approach to technology transfer. Six times a year since 1981, the company has held conferences that bring together representatives of universities and technology-based firms. The primary purpose of these meetings, of course, is to discuss the schools' research projects and determine how they might fit into the companies' product lines.

A. L. Frye, Aladdin's vice-president for business development, contrasts the company's strategy with that of others with which he has been associated. "I used to travel to universities to evaluate technologies for possible licensing and found the hit ratio was very low," he recalls. "The company would spend plane fare, expenses, and a few days of my time and come away with nothing."

Aladdin, UPI, and Research Corp. have staked out a piece of the high technology industry that few others seem willing to enter. "There is a very long lead time," Miles stresses, with at least five years between licensing a new technology and seeing any royalties. "You need a lot of financial staying power." Both Miles and Research Corp.'s Bacon see most of their competition continuing to come from individual patent attorneys working for their own clients or from large, diverse R&D institutions such as Battelle (Columbus, Ohio) and Arthur D. Little (Cambridge, Mass.). Given the tough going for experienced hands like UPI and Research Corp., it's unlikely that many others will be tempted to join the fray. "This isn't something you can just jump into," says Miles. □

—***Ben Daviss***

U. of Illinois's Plato teaching software, developed by Donald L. Bitzer (above), was licensed by UPI to Control Data.

TV helps bridge the learning gap

In most respects it is a typical high-school scene: Teenagers sit at desks, take notes, study textbooks, puzzle over problems. The difference: The teacher is many miles away, present in the classroom only as an image and voice emanating from a television set. Video cameras and microphones in the class-

room assure that the students' faces are seen and their questions heard.

Such interactive TV hookups are starting to appear in many rural communities where students would otherwise have to travel long distances to attend classes. Several colleges have also begun using similar systems to transmit courses to professionals at their workplaces. And a July ruling by the Federal Communications Commission (FCC) should make interactive TV more readily available for educational purposes.

To date, most interactive educational TV has relied on a group of frequencies, called Instructional Television Fixed Service (ITFS), that are higher than those the networks use and lower than microwave. One attraction of ITFS is that each receiving station needs only a small, inexpensive dish antenna. Another advantage is the signal's short range—a central transmitter covers a 20-mile radius—which allows the same channel to be shared by several users in a region without interference.

Traditionally set aside for local community services, ITFS was for many years an underutilized resource. Then in 1983 the FCC moved to stimulate usage by allocating two groups of ITFS channels for commercial purposes and allowing users of the four other channel groupings to lease excess capacity to commercial program sources such as Home Box Office. Suddenly the channels that nobody wanted had become hot properties, and the FCC received a flood of applications from schools eager to stake a claim.

Partly in response to the concerns of educators, the FCC declared in July a one-year period during which local institutions will get priority for use of ITFS channels. Applications by national broadcasters will be put on hold until July 1986.

ITFS is far from ideal, however. Usually it provides two-way audio, but video transmission in only one direction: Students see the teacher but not vice versa, and students at one remote learning site cannot see students at another site who are taking the same course. This limitation arises because while ITFS receivers are small and cheap, the transmitters are not. Many school systems buy only one, stationing it at the central school where the teacher is.

For two-way video, which is considered essential for teaching and supervising pre-college students, schools are turning to microwave links. The relatively small microwave transmitters can be stationed at each remote learning center. In addition, the microwave signal can be boosted by repeaters to go hundreds of miles—much farther than is possible with ITFS.

The advent of commercial Direct Broadcast Satellite (DBS) services, however, is threatening to crowd educational institutions out of those parts of the microwave spectrum allocated to them by the FCC. The commission

has ruled that as of September 1988, schools will have secondary status at the frequencies they have been using most often (12.2–12.7 gigahertz); if there is any interference with a DBS signal, the institution will need to clear it up immediately.

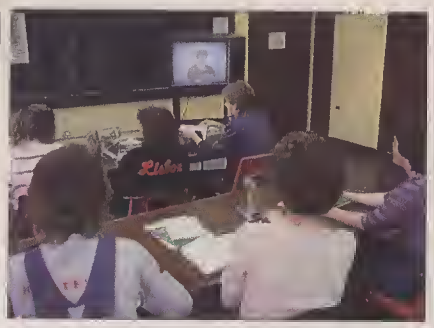
Microwave links are already in place at Kirkwood Community College (Cedar Rapids, Iowa) and at several high schools in small midwestern communities. In the Kirkwood system, eight learning centers dot 4500 square miles of Iowa farmland. Each center is a miniature TV studio, equipped with video cameras and microphones; a student who wants to speak simply presses a button on the mike and chimes in. A technician then switches on the camera in that room, and a computer automatically reroutes the video transmission so that the image of the speaking student appears on the teacher's monitor as well as on the TVs watched by the students at other centers.

By letting the students see each other on the screen, two-way video reduces the feeling of anonymity associated with TV-taught classes. It also allows the teacher more opportunity to check on those who remain silent or on the unruly few who would disrupt class. "It's essential for the teacher to see the high school student," says Anne Volkman, a teacher at Morning Sun (Iowa) High School.

Another means of transmitting televised instruction—cable—offers the ability to reach directly into the students' homes; it also produces higher-quality images than either microwave or ITFS. Trempealeau County in Wisconsin uses it because the community took over a failed commercial cable venture. In most cases, however, cable reaches fewer homes than educators would like. Also, where commercial and educational interests collide in cable, education usually loses. In Ohio, for example, the Columbus Technical Institute lost its access to the local QUBE cable network in favor of the more lucrative commercial users.

Educationally, interactive television seems to work. "We've tested these students against their counterparts in regular classes, and we haven't found any difference," notes William Urban, superintendent of the Trempealeau County schools. Many students enjoy the novelty. In addition, "it's easier to voice your ideas when the teacher isn't in the room," says Doris Beres, a student at Kirkwood.

For some types of instruction, TV can actually be more effective than



Two-way TV brings community college to widely scattered sites in rural Iowa.

"live" teaching. For example, it is easier to demonstrate how to dissect a fetal pig over television—as is done at Morning Sun—than in a classroom with 20 students crowding around a lab bench. And the television camera can be attached to a microscope to show students in distant laboratories what to look for in their own microscopes.

Interactive TV is also becoming increasingly popular for adult education and professional development. The Illinois Institute of Technology, Georgia Tech, and Stanford, for example, use ITFS to provide local businesspeople with graduate courses in management, engineering, and science. And both Indiana University and the University of South Carolina have established statewide networks that aim to keep professionals up to date on developments in their fields. Perhaps most ambitious of all, Chico State University in California has begun offering some of its graduate-level classes to students as far away as Johnson City, Tenn. In fact, Chico's satellite hookup could allow the school to transmit courses throughout the Pacific Basin—a third of the globe. □ —***Ted Anton***

Sensing sound to avert catastrophe

Just as a smoke detector can alert a homeowner to a fire but fail to tell whether it is from burning toast or a raging inferno, many nondestructive evaluation techniques warn of the presence but not the severity of a structural flaw. Recent advances in acoustic emission (AE) sensors, however, may enable safety inspectors to distinguish readily between serious and minor defects in systems ranging from airplanes to nuclear power plants. In recent Federal Highway Administration tests on bridges, for example, the new type of sensor has discerned signals that portend fracture.

Acoustic emission sensors "listen" for the sound waves generated by structural defects that are undergoing change. This effect has been known for centuries, based on such evidence as the creaking of wooden beams and the crackling of tin being bent. Most materials emit at frequencies too high for humans to hear, but ultrasonic transducers can detect them. And because it does not require probing the sample with external energy, acoustic emission technology permits continuous monitoring of a structure, which is not practical with active evaluation methods such as ultrasound and x-rays.

Present AE sensors are generally of such low fidelity that little detailed information can be inferred from their signals. But a new device developed at the National Bureau of Standards (NBS) promises to change that.

A conventional AE sensor consists of a flat disk of a piezoelectric material, which generates an electrical voltage in response to mechanical pressure. A major source of signal distortion is the disk's relatively large size, typically half an inch in diameter. High-frequency vibrations, with wavelengths smaller than the disk, can go undetected because one portion of the sensor feels a compression peak at the same time that another portion of the sensor is experiencing a pressure minimum. A similar effect renders the conventional AE detector insensitive to sound waves coming from certain angles.

The acoustic events that these conventional sensors do pick up often yield signals of such complexity that interpretation is next to impossible. Sound waves reflect off the back of the disk and overlap with the incoming waves; the resultant "ringing" is an artifact of the detector and tells little about the event being sensed. In addition, the disk produces a voltage when compressed either vertically or horizontally, further complicating the signal.

The NBS transducer bypasses these problems by using not a flat disk but a slender piezoelectric cone. Tapering down to a tip only 1 millimeter across, the conical device is sensitive to a wide range of frequencies, up to at least 1 megahertz. It senses only vertical motion, thereby simplifying signal analysis, and unlike a flat disk, it responds equally to vibrations coming from all directions. This ominidirectional sensitivity can help pinpoint a flaw, some-

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thing not practical with flat disk devices. Two or three transducers are placed at different points on the structure; comparing the instant that the pulse of sound from a growing defect reaches each sensor gives sufficient data to locate the flaw.

The device's shape also reduces ringing, according to its principal developer, NBS scientist Thomas M. Proctor, Jr. The tapering sides attenuate the sound waves so that there is less energy to reflect from the element's rear face, he notes. Such reflection is further suppressed by backing the piezoelectric with an irregular brass polygon; the acoustic characteristics of brass are similar to those of the piezoelectric, so energy is transmitted, rather than reflected, at their interface.

The NBS device by itself is not sufficient to warn of impending failure, but without it, or some other high-fidelity transducer, says Proctor, "you don't have a prayer." In fact, the advent of such a faithful transducer has prompted others to develop the signal processing techniques necessary to interpret the data.

The basic procedure consists of two steps. First, the conical sensors will be used on reference structures to accumulate a catalog of signals that accompany known defects. The output from a sensor—on, say, a bridge or an airplane wing—can then be electronically checked against these references. If a match is found with a signal that indicates impending fracture, for example, a specific warning can be sent, perhaps telling the pilot to land the plane as soon as possible. Such real-time analysis requires significant improvements in signal processing over what is now available, says Proctor, but "the transducer has at least opened the door to this possibility."

In addition to monitoring flaws, acoustic emission technology could aid automated manufacturing. For example, a high-fidelity transducer could "hear" a drill bit touch the workpiece before any mark is observed, allowing closer monitoring and control of an unmanned machining center.

But the main use of the sensors is still in research laboratories. That's partly due to a deficiency of the device. "The conical tip is very fragile," explains Harold Berger, president of Industrial Quality (Gaithersburg, Md.), which markets tranducers based on NBS's unpatented technology. "A more rugged design is needed for industrial applications." □ —***David I. Lewin***

RESOURCES

Information sources for topics covered in our feature articles

Home movies made simple, p. 16

"Recording video camera in the Beta format." Seiji Sato, Koichi Takeuchi, & Masanobu Yoshida. *IEEE Transactions on Consumer Electronics* (New York), Aug. 1983.

"Home movie revolution." Stuart Diamond. *New York Times,* June 14, 1984.

"Is there room for 8mm video?" Barbara Buell, Larry Armstrong, & Andrea Gabor. *Business Week,* Dec. 24, 1984.

"Kodak ventures into video." Hans Fantel. *New York Times,* Feb. 1, 1984.

"Home video: the next wave." Stuart Weiss. *Business Week,* Aug. 19, 1985.

Digital signal processors, p. 25

Introduction to Communication Systems. Ferrel G. Stremler. Reading, Mass.: Addison-Wesley, 1982. Review of the mathematical fundamentals of signal processing.

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"Image processing by computer." T. M. Cannon & B. R. Hunt. *Scientific American,* Oct. 1981. Review of digital image enhancement techniques.

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"Chip design made easy." Jeffrey N. Bairstow. *High Technology,* June 1985. Surveys advances in custom integrated circuit design.

IBM Journal of Research and Development. March 1985. Issue focusing on signal processor technology. #G322-0140-0. Available from IBM, Armonk, NY 10504.

Recycling, p. 32

Contacts

National Solid Wastes Management Assn., 1730 Rhode Island Ave., NW, Suite 1000, Wash., DC 20036, (202) 659–4613. An authority on handling and recovering municipal wastes.

National Assn. of Recycling Industries, 330 Madison Ave., New York, NY 10017, (212) 867–7330. Represents dealers, processors, and consumers of recycled materials.

Society of the Plastics Industry, 355 Lexington Ave., New York, NY 10017, (212) 503–0600. Major trade group of plastics manufacturers and researchers.

Plastics Institute of America, Stevens Inst. of Technology, Castle Point Station, Hoboken, NJ 07030, (201) 420–5552.

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"Plastics recycling: a revival." *Chemical Engineering,* June 25, 1985.

The Impacts of Material Substitution on the Recyclability of Automobiles. R. Andrew Blelloch, ed. New York: American Soc. of Mechanical Engineers, 1984. Technical constraints on recycling automobile materials.

Recycling, Fuel and Resource Recovery: Economic and Environmental Factors. Martin Grayson, ed. New York: Wiley, 1984. Good overview of current recycling and recovery technology.

R&D consortia, p. 42

"Cooperative R&D: a regional strategy." William C. Norris. *Issues in Science and Technology,* winter 1985. Control Data's chairman explains why states should pool their university and industrial resources in developing technologies and competing in international markets.

"R&D consortia: Can U.S. industry beat the Japanese at their own game?" Jonathan B. Tucker. *High Technology,* Oct. 1984. An overview of the incentives to form consortia and a description of several of the earliest groups' activities.

"The MCC payoff: getting the technology back home." Clinton Wilder. *Computerworld,* June 10, 1985. Examination of how MCC hopes to ensure the efficient transfer of the technology it develops.

"Why the industry is slow to enter joint research." B. J. Spalding. *Chemical Week,* May 15, 1985. Report on why the secretive chemical industry is often reluctant to form R&D consortia.

"R&D consortia aim at improving defense software." Suzanne Perney. *High Technology,* March 1985. Covers DOD-sponsored Software Engineering Inst. and a software consortium proposed by defense contractors.

Technology centers, p. 48

Contact

Office of Public Affairs, National Science Foundation, 1800 G St., NW, Wash., DC 20550, (202) 357–9498.

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TECHSTARTS

Gold Hill Computers:

TEACHING LISP TO PERSONAL COMPUTERS

Personal computers aren't powerful enough for large-scale artificial intelligence programs, but they make relatively inexpensive vehicles for developing more modest-sized applications and for teaching AI programming in universities and businesses. Gold Hill Computers' pared-down version of Common LISP (the dialect of the LISP programming language in widest commercial use) has made the company the market leader in AI languages for the IBM PC. Gold Hill plans to build on its head start in an increasingly crowded market by introducing new programming tools, such as a LISP compiler and a graphics package (scheduled for late this year) and software to help programmers develop expert systems (scheduled for 1986).

Financing: $500,000 in venture capital from Memorial Drive Trust, Churchill International, and Fairfield Venture Management.

Management: Several company members come from MIT's Artificial Intelligence Laboratory, including founder and VP of R&D Gerald R. Barber, who was a research scientist there, and board member Patrick Winston, the lab's current director. President Carl Wolf headed a microcomputer software consulting company, the Wolf Group, and was formerly president of the Interactive Data Corp. subsidiary of Chase Manhattan Bank.

Location: 163 Harvard St., Cambridge, MA 02139, (617) 492–2071.

Founded: January 1984.

Gold Hill president Carl Wolf demonstrates the company's version of LISP—a popular programming language for artificial intelligence software—for the IBM PC.

International Biotechnologies:

SELLING KNOW-HOW IN KITS

International Biotechnologies Inc. (IBI) hasn't quite learned how to bottle its molecular biology expertise, but it has come pretty close by selling "product systems"—kits made up of laboratory apparatus, enzymes, ultrapure reagents, computer software, and step-by-step instructions for carrying out procedures such as cloning and DNA sequence analysis. Many of the more than 200 components of these systems are manufactured with the company's proprietary technology. To market the systems, IBI uses a direct sales force and catalog mailings to reach potential customers at universities, research institutes, and industrial R&D groups working in fields that range from healthcare to energy production.

Financing: Venture capital financing from investors including L. F. Rothschild, Unterberg Towbin Venture Capital Fund, Prime Capital Limited Partners, Alan Patricof Associates, and Olin Corp.

Management: John Kreisher, chairman and CEO, was president and owner of Aaron Associates, a toxicology and biotechnology consulting firm, and previously was associate director of the Council for Tobacco Research. Nelson Martin, president and COO, was senior VP of Johnson & Johnson's Irex diagnostic imaging division.

Location: 275 Winchester Ave., New Haven, CT 06535, (203) 562–3878.

Founded: December 1980.

BidNet:

PUTTING SUPPLIERS IN TOUCH WITH DEMAND

Although bidding for large military contracts is a finely choreographed process, procedures that apply to other goods and services are often haphazard. Until recently, vendors had no manageable way of learning about bid requests from government agencies, hospitals, universities, and other nonprofit organizations. Now there's BidNet, which collects bid requests from over 7000 purchasers, computerizes them, and sends summaries to potential vendors among their subscribers by telex, computer, or mail. For $1200 a year, subscribers receive either state and local or federal coverage; for $1800, they get both. So far, BidNet has no direct competitors.

Financing: First-year operating capital from Best Products, a nationwide retailer. In April, Dun & Bradstreet became an equity partner.

Management: President Joel Koblentz was executive VP of Best Products. Executive VP Andrew Lupton was Senior VP of the Academy for Educational Development, where he directed the management division. Mary Brady, VP of network services, managed telecommunications projects for the Agency for International Development and the U.S. Information Agency.

Location: 4350 East West Hwy., Suite 1100, Bethesda, MD 20814, (301) 986–4747.

Founded: April 1983.

EARTH STATION BUSINESS IS LOOKING UP

Vendors foresee rapid expansion in private satellite networks

Since AT&T's divestiture, a growing array of alternatives have joined the traditional telephone network as a means of transmitting corporate data. One such option is the private satellite network, which is finding increased application in financial transactions, retail point-of-sale, process control, and branch office administration.

A key component of such a network is the earth station, a device for sending signals to, and receiving them from, a satellite. Smaller stations, with dish diameters of less than two meters, offer the advantages of minimal impact on the environment, low cost, and modest space and structural requirements. Vendors hope to compete with the common carriers on the basis of more cost-effective service and point-to-multipoint capabilities, with no decrease in transmission quality.

Transmission frequencies in satellite hookups may be in either of two ranges: C-band (4–6 gigahertz), which is less susceptible to atmospheric interference, or Ku-band (12–14 gigahertz), which allows signals to be aimed more precisely. The industry trend is toward medium- to high-speed two-way products that operate in Ku-band.

This market is still in its infancy—Hambrecht & Quist estimates 1985 sales at $20 million—and its growth rate may at first be inhibited by the reluctance of corporate communications managers to abandon the familiar telephone network for a relatively new technology. However, several factors could push demand to $150 million within two years. AT&T recently stimulated corporate interest in bypassing the telephone network when it raised the price of its leased lines. The FCC has made it easier to get stations installed by loosening the permit requirements for Ku-band equipment and by increasing the availability of bandwidth for small-diameter stations, which helps prevent conflicts with frequencies used by other services. And the cost of stations is decreasing, thanks to improvements in fiberglass materials used for station antennas and the availability of gallium arsenide devices (which have led to lower-priced, higher-powered amplifiers).

by Douglas F. Whitman and Roland A. Van der Meer

Several firms employ business strategies that make them worth investor interest. Among them are Avantek (Milpitas, Cal.), California Microwave (Sunnyvale, Cal.), and Equatorial Communications (Mountain View, Cal.).

Avantek (OTC: AVAK) is a leading supplier for the commercial communications and defense electronics markets. Its major sources of revenue are microwave and satellite components and systems. Avantek offers a medium- to high-speed Ku-band dish, currently priced at $15,000. The company should be able to lower this price over the next few years by producing its own satellite components, thus avoiding the markups and product delays that reliance on outside vendors might bring. Avantek has also sharply increased its planned spending for marketing and R&D in 1985.

In 1984, the company posted revenues of $159 million, which yielded a net income of $17.1 million, up from $119 million and $11.9 million in 1983. Earnings per share increased from 63¢ in 1983 to 90¢ in 1984.

California Microwave (OTC: CMIC) manufactures microwave systems, satellite communications systems, and signal source components for sale to commercial and government markets. The company's expertise has been in developing customized turnkey systems requiring little network management by the end user. These include large master earth stations at network hubs, communications software, and small earth stations for each transmitting/receiving site. The medium- to high-speed Ku-band mini-station is available separately at $30,000, and the company has targeted initial sales to the long-distance carriers. AT&T has already chosen California Microwave as a vendor for these stations.

Erik van der Kaay, VP of Telecommunications at Avantek, phones by satellite.

Last year, revenues were $112 million, profits were $5.8 million, and earnings reached 70¢ per share—all up from 1983, when sales were $101 million, profits $5.3 million, and earnings per share 65¢.

Equatorial Communications (OTC: EQUA) sells small earth stations that may be used in conjunction with the company's transponders and packet-switched network services, thus providing the customer with a complete satellite network service. The firm has been a leader in selling low-cost (under $3000), low-speed, receive-only C-band antennas for one-way distribution of time-critical general news, financial news, and commodity information. Customers have included the major news services, Dow Jones, and Telerate. New interfaces should allow expansion into markets for corporate database communications and distribution of personal computer software. Equatorial has recently expanded its offerings with a two-way station selling for $6000.

The firm reported earnings of 50¢ per share in 1984, based on $38 million in revenue and $5.7 million in net income, an increase from 1983's earnings of 30¢ per share, revenue of $17.8 million, and profits of $2.7 million. □

Douglas F. Whitman is senior communications analyst at Hambrecht & Quist, a San Francisco–based investment banking firm, and Roland A. Van der Meer is an associate with H&Q Communications Ventures.